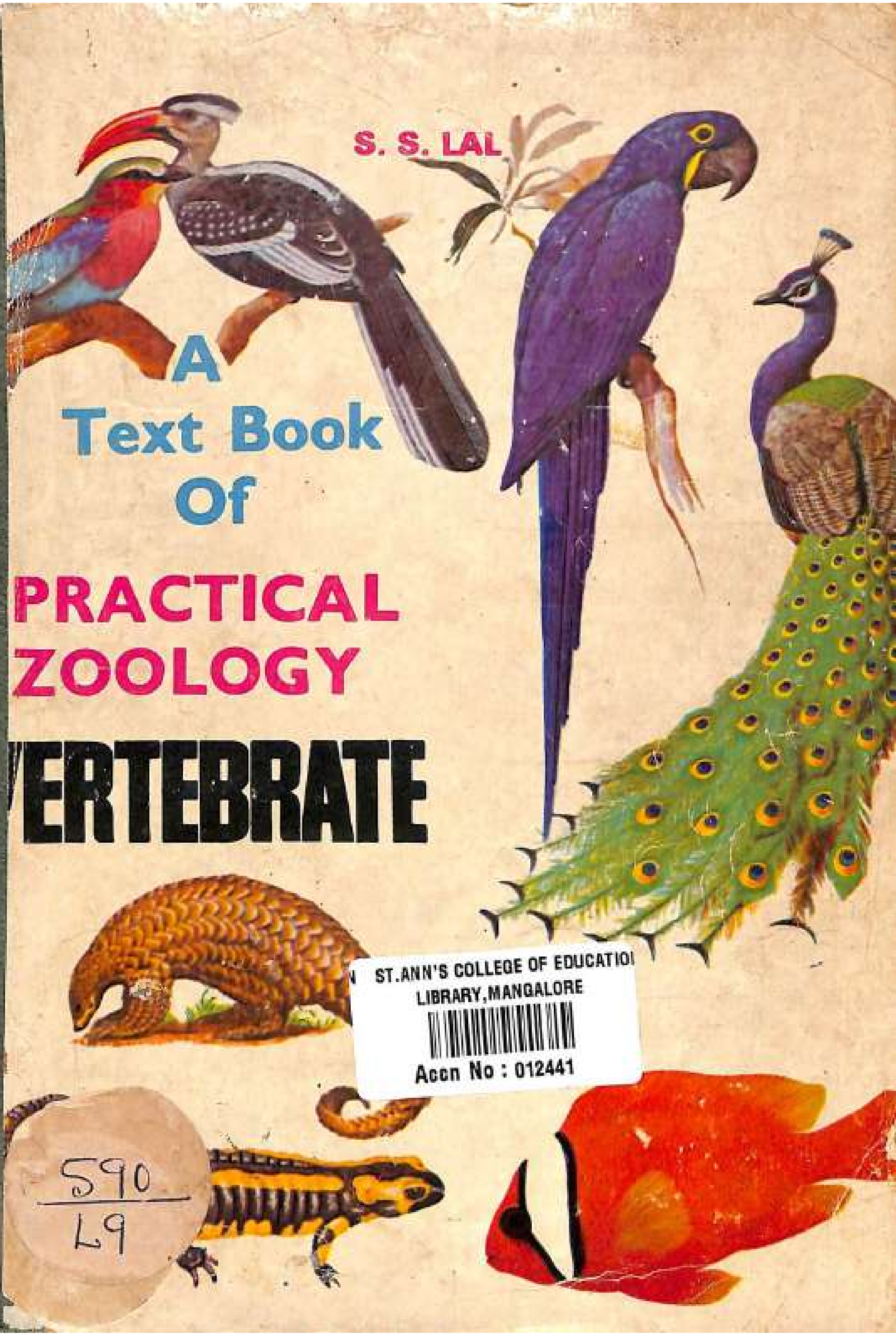
S. S. LAL

A Text Book Of PRACTICAL ZOOLOGY VERTEBRATE



A
TEXT BOOK
OF
PRACTICAL ZOOLOGY

VERTEBRATE

A Text Book Of PRACTICAL ZOOLOGY

VERTEBRATE

S. S. LAL Ph.D.
DEPARTMENT OF ZOOLOGY
MEERUT COLLEGE, MEERUT.

THOROUGHLY REVISED AND ENLARGED THIRD EDITION : 1975–76

PRICE : **17·50** RUPEES

PRINTED AND PUBLISHED BY RAKESH K. RASTOGI FOR RASTOGI PUBLICATIONS, SHIVAJI ROAD, MEERUT–250002 AT PIONEER PRINTERS, SHIVAJI ROAD, MEERUT–250002. (INDIA)

Preface

With the enormous volumes of researches that find place in science each year, it becomes rather difficult to sort out the meaningful and to present it in a comprehensive manner. It needs constant examination of the new data. In the present work, all the chapters have been written in the light of recent knowledge. The presentation of the Vertebrate Practical Zoology follows essentially the pattern set earlier by the Invertebrate Practical Zoology. It has been brought into line with recent studies in systematics and new material supercedes the old pattern usually seen in other books available on this subject. Much emphasis has been laid on the drawings pertaining to their simplicity and clarity of style.

In the very beginning practical use of microscope, general method of microscopic preparations, preparation of fixatives, stains and other reagents and preparation of permanent slides (mountings) have been dealt with. All the vertebrate museum specimens have been kept in one chapter. Similarly, all the slides on histology have been arraged in one chapter and those of embryology in another. In the end, chapters on Comparative Osteology and Dissections have been specially designed for this work

The occasion for third edition of this book has given me an opportunity to improve on the work and to make certain additions which were suggested by friends and fellow teachers. Approximately in every chapter the additions have been made, about 45 museum specimens and 10 slides have been added. The illustrations of comparative osteology have been simplified to make it more useful to the students. A chapter on Physiological Experiments etc. has been given in the end to make the book complete in itself.

I express my sincere gratitude to Prof. R. L. KOTPAL, the celebrated author of the well-known ZOOLOGY PHYLUM BOOKS for his invaluable guidance and assistance in every sphere during the preparation and revision of this book.

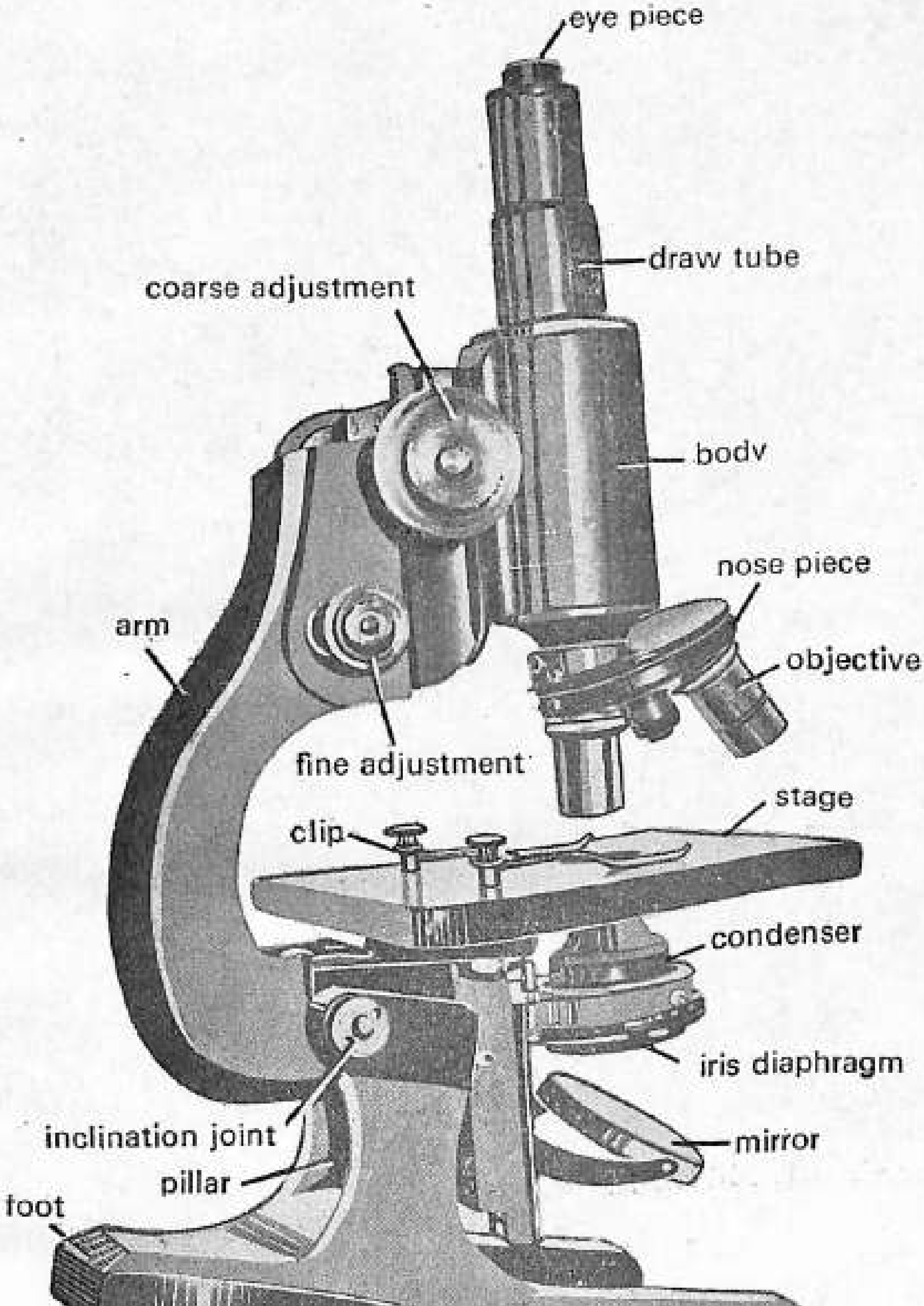
I am very much grateful to the fellow teachers and students who have obliged me by sending their valuable opinions and suggestions.

Zoology Department
Meerut College, Meerut.

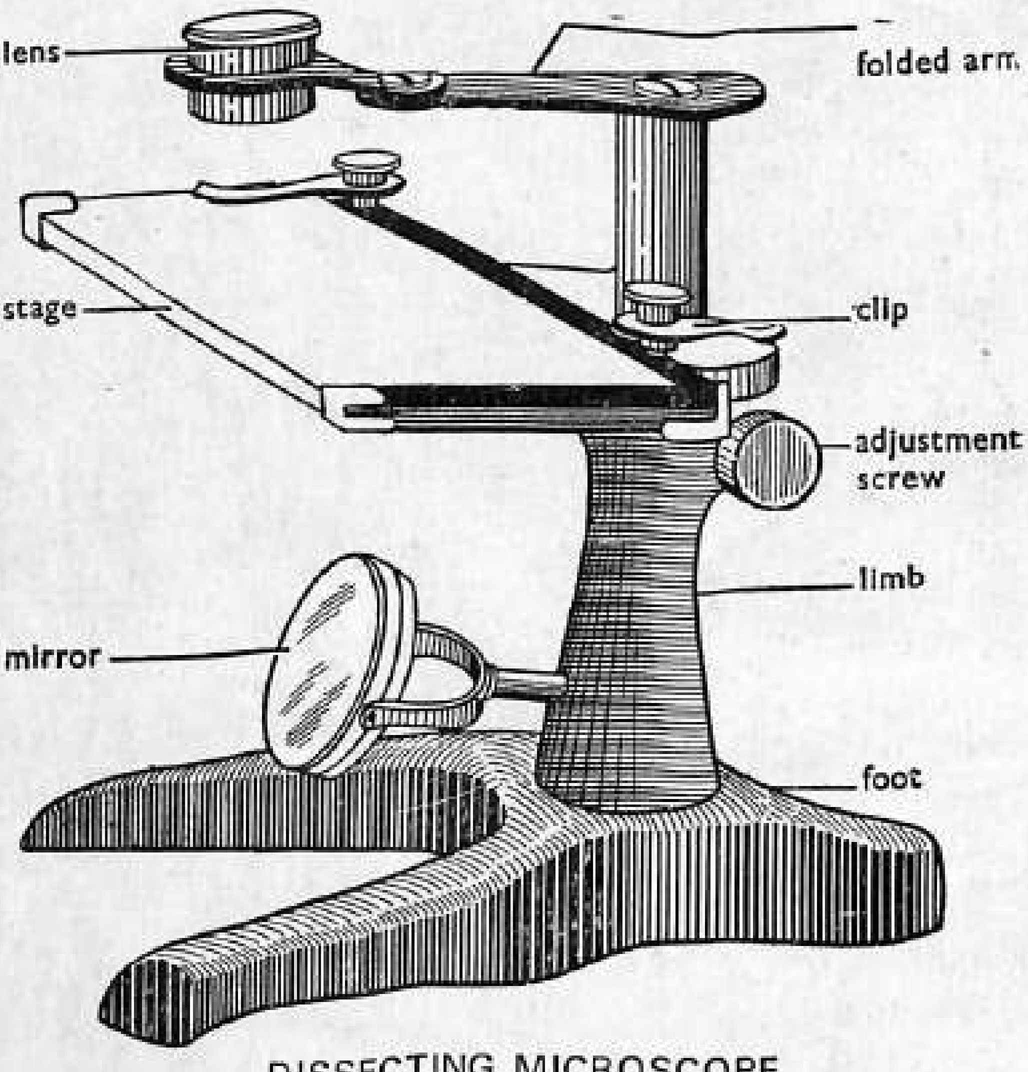
S. S. LAL

Contents

580
48



COMPOUND MICROSCOPE



DISSECTING MICROSCOPE

1

Chapter 1

General Method of Microscopic Preparations

The processes by which the detailed structure, both morphological and histological, and physiological aspects of animals are known, come under the domain of practical zoology. For undergraduate students of Indian Universities the practical work pertaining to zoology includes :

(1) Microscopic preparations of slides.
(2) Mountings.
(3) Culture of animals.
(4) Study of prepared slides.
(5) Museum specimens.
(6) Dissections.
(7) Physiology.
(8) Biochemistry.
(9) Microbiology.
(10) Ecology, etc.

The larger specimens, such as prawn, pila and cockroach, are preserved in preservatives like formalin or alcohol for the study of their external features and they do not need any elaborate process. Microscopic study may be done by **temporarly** or **permanently** mounting the organism on the slide. Temporary mounts can be made in water, Glycerine or Ingol's iodine solution. For example, living *Cyclops*, *Amoeba*, *Paramecium*, etc. are kept on the slide in a drop of water and cover-slip is put over the object and thus it can be examined under the microscope. For clarity of structures of small animals, microorganisms and histological studies of tissues, an elaborate technique is employed for making their permanent preparations. These smaller objects are mounted in balsam on a slide. There is a series of processes by which a living organism or its tissue is made fit for microscopic examination in a permanent state. The utility of permanent preparation is that the animal cell or tissue remains as such without undergoing major changes. The permanent preparation includes :

(1) Killing and narcotization.
(2) Fixing.
(3) Washing.
(4) Staining.
(5) De-staining or removal of excess of stain.
(6) Dehydration or removal of water.
(7) Clearing or de-alcoholization.
(8) Mounting on slide.
(9) Labelling.

1. Killing & Narcotization

The first step in permanent preparation is killing instantaneously in order to prevent the change in form of the object as it had in living condition and immediately fixing the object. Sometimes killing is preceded by *narcotization*. The narcotics used are **chloroform**, **menthol**, **ether**, **alcohol** and **acetone chloroform**, etc. The purpose of narcotization and killing is important as to have the same form and chemically constructed tissue or organism as it had during its lifetime. In certain cases, in smaller animals, killing is done by heating. In the case of the whole mounts and microorganisms, certain chemicals, like **corrosive sublimate**, bring about killing and fixation simultaneously.

2. Fixing

Fixing is done with various fixative agents for histological elements. Fixing is essential in every type of microscopic preparations either for sections or for whole mounts and also in larger specimens. The function of fixation is manifold.

(1) The tissues become hard and the hardening resists further post-mortem changes.
(2) Fixative agent **coagulates** and renders insoluble elements of tissues which are dissolved in further processing.

(3) The fixative agent renders insoluble the various constituent elements of cells, alters their refractive indices and thus makes them optically differentiated under the microscope.

Various **fixative agents** generally used are **absolute alcohol, 90 per cent alcohol** plus **glycerine, picric acid, corrosive sublimate, formol, osmium tetroxide** and **nitric acid** with or without water.

3. Washing

Washing is essential as by this process the uncombined and excess of fixative agent is removed. The presence of fixative agent in tissues or cells will inhibit good staining. The washing agent depends upon the type of fixative agent used. As picric acid in water is removed by water, picric acid in alcohol is removed by 70 per cent alcohol. Formol and corrosive sublimate are washed with water distillate. Sublimate is washed in alcohol.

4. Staining

The tissues or cell components are stained in various dyes. The dye makes the tissues distinct in its histological sphere. The various **dyes** are **Orange G., Bordeaux red, sudans, congo red, Alizarine oxyquinoine, methylene blue, neutral red, borax carmine, haematoxylin, picro-indigo carmine, eosin,** and **Gower's carmine.** Mainly two kinds of stains are used :

(1) **Nuclear stains** which stain nuclear parts of the cell, such as Delafield's or Erhlich's haematoxylin.

(2) **Cytoplasmic stains** such as borax carmine, picro-indigo carmine, Gower's carmine and eosin, etc. which stain cytoplasm.

For general staining borax carmine is used. Aqueous stains are prepared in water, whereas alcoholic stains are prepared in alcohol. When a single stain is used the process is called as *simple* or *single staining*. In some cases two stains, i.e., nuclear and cytoplasmic are used and this process is called as *double staining*.

5. De-staining

The removal of excess of stain is called as *de-staining* or *differentiation*. De-staining agents are acid alcohol or acid water. The acid alcohol is used with alcoholic stains, while acid water is used with aqueous stains.

6. Dehydration

This process is meant for removal of water from the tissues. The dehydration prevents putrefaction or decaying and maintains the same shape and size of tissues or cells. The moisture or water in tissues absorbs various germs of destructive nature so that the tissue may be destroyed, hence the necessity of dehydration. Dehydration is done by passing the mounting material through various grades of alcohol, such as 30, 50, 70, 90 and 100 per cent alcohols. The tissue is soaked in gradually increasing strengths of alcohol. The lower grades of alcohol, such as 30, 50 and 70 per cent alcohols, are prepared either from 90 per cent or absolute alcohol. The dehydration is carried out in corked or glass-stoppered tubes.

7. De-alcoholization or Clearing

After dehydration, transparency in tissues is obtained by treating with a clearing agent which removes alcohol and makes the tissue clear and transparent. The clearing agents are cedar wood oil, clove oil, xylol and benzol, etc. Xylol is most commonly employed and it makes the tissues hard and brittle. Clove oil is a superior clearing agent specially in the whole mounts. It also possesses a higher index of refraction than balsam mounting media.

8. Mounting

Mounting forms the end of permanent preparation. The choice of mounting media is not much but they should have the same refractive index as that of the cleared tissue. The refractive index of such a stained, dehydrated and cleared cell is $N = 1{\cdot}54$. Canada balsam has almost the same refractive index. Mounting is an easy process. The tissue is kept over glass slide in a drop of balsam and cover-slip is lowered slightly. After mounting, the slide may be kept for drying in a hot chamber. The excess of balsam on the slide, as generally happens with beginners, should be removed with cotton soaked with xylol or 90 per cent alcohol. This should be done when the balsam has dried. For much better finishing the edge of the cover-glass may be ringed with a cement such as gold size or a varnish. The air bubbles present in balsam under cover-glass should be removed by gentle heating.

During all the chemical bathing of tissues, two changes of each reagent are necessary. The time of keeping tissue in various reagents may vary from 5 to 15 minutes.

9. Labelling

After mounting the slides are labelled. Preferably use printed labels or make the labels from ordinary paper. Write over the lable the name of the animal or mount, date, time and your name.

I. Chart for single staining

Fix the material
↓
Wash in tap water
↓
Dehydrate with
30 per cent alcohol
↓
50 per cent alcohol
↓
70 per cent alcohol
↓
Stain in Borax carmine or
Eosin or Picro-indigo carmine
↓
De-stain in acid alcohol
↓
Wash with 70 per cent alcohol
↓
Dehydrate with
90 per cent alcohol
↓
100 per cent alcohol
↓
De-alcoholize or clear in
clove oil or xylol
↓
Mount in canada balsam
Time 5–15 minutes in each reagent.

Precautions and Instructions

1. The articles, such as slides, cover-slips and instruments should be perfectly cleaned.
2. The working place should be kept in order.
3. During dehydration the tissues should be kept in tightly-closed cork or glass-stoppered tubes. The opened tube will spoil material by absorbing moisture from atmosphere. Even breathing closely with dehydrating tube is undesirable.
4. The change of solution should be done very quickly, reducing time of exposure to atmosphere to minimum.
5. The chemicals used once should not be reutilized.
6. The canada balsam used should be clean, dust-free and not viscous.

II. Chart for double staining

In this, nuclear and cytoplasmic stains are used. The former is used first.

Fix the material
↓
Wash in tap water
↓
Stain in haematoxylin
↓
De-stain in acid water
↓
Wash in tap water (bright blue colour)
↓
Dehydrate with 30 per cent alcohol
↓
70 per cent alcohol
↓
90 per cent alcohol
↓
Stain in Eosin
↓
Wash with
90 per cent alcohol
↓
100 per cent alcohol
↓
Clear or de-alcoholize with xylol or clove oil
↓
Mount in canada balsam
Time 5–15 minutes in each reagent.

Chapter **2**

Preparation of Permanent Slides (Mountings)

Necessary instruction for the permanent mountings and staining, etc.

(1) Study thoroughly about the structure which is to be stained and mounted.

(2) Dissect the animal to take out structure to be mounted (e.g. neural complex of *Herdmania*) and follow the method given in Chapter 1.

(3) After mounting, study and draw the slides prepared by you with the help of the Practical Book.

A. PROTOCHORDATES

[1] *Amphioxus*—Oral hood

Procedure—Take out oral hood, wash in water, stain in borax carmine, dehydrate and mount in canada balsam.

Characters—(1) It is the anteriormost structure containing 10–11 pairs of tentacles or cirri. (2) It leads into vestibule, which in turn opens into pharynx through velum (Fig. 2-1).

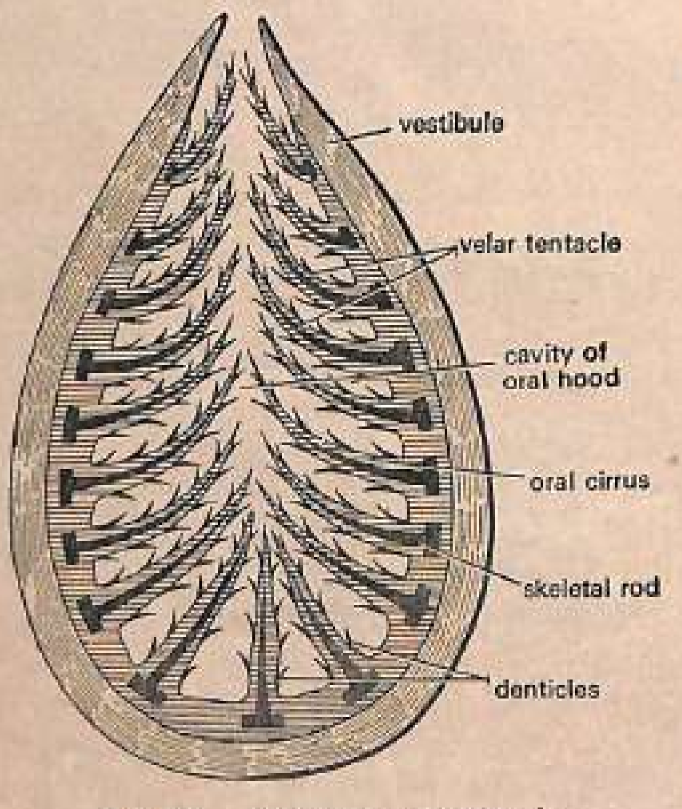


Fig. 2-1. *Amphioxus*. Oral hood.

[2] *Amphioxus*—Velum

Procedure—Dissect from ventral side. Velum is found at the base of vestibule. Wash, stain in borax carmine, dehydrate, clear and mount.

Characters—(1) Velum is composed of velar ring, sphincters and about 12 backwardly directed velar tentacles having sensory papillae and cilia. (2) Velum forms a sieve-like structure (Fig. 2-2).

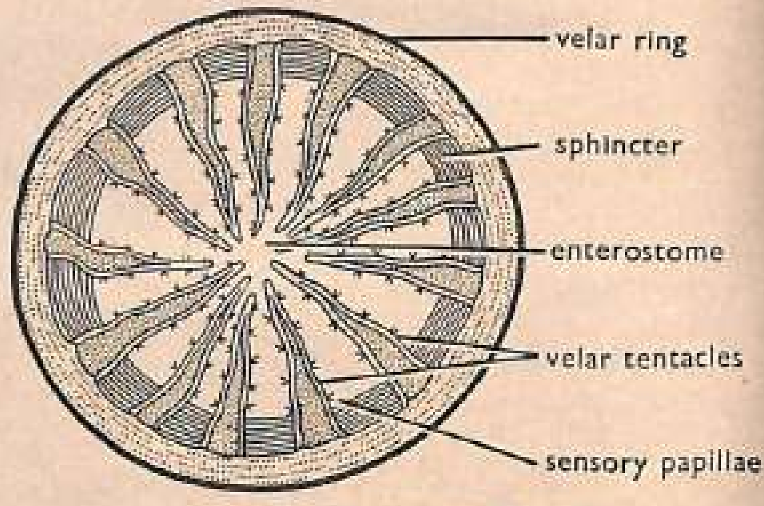


Fig. 2-2. *Amphioxus*. Velum.

[3] *Amphioxus*—Pharyngeal wall

Procedure—Cut portion of pharynx, wash in water, stain in borax carmine, dehydrate and mount.

Characters—Pharynx contains gill-slits supported by skeletal rods. On the ventral side of pharynx is endostyle and on the dorsal side is epipharyngeal groove (Fig. 2-3).

[4] *Herdmania*—Neural complex

Procedure—Neural complex is embedded in body wall in the middle of inter-siphonal region. Take out neural complex by needles,

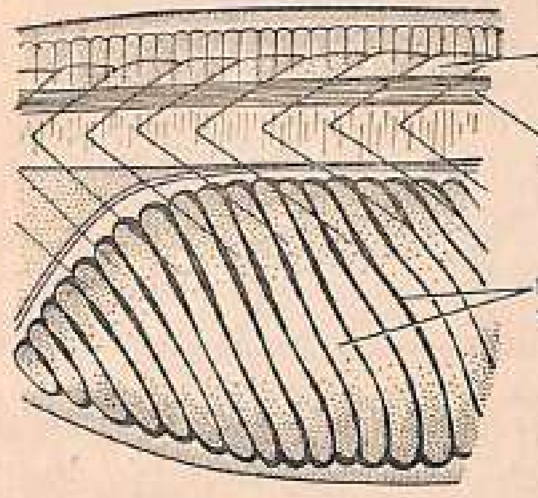


Fig. 2-3. *Amphioxus*. Pharyngeal wall.

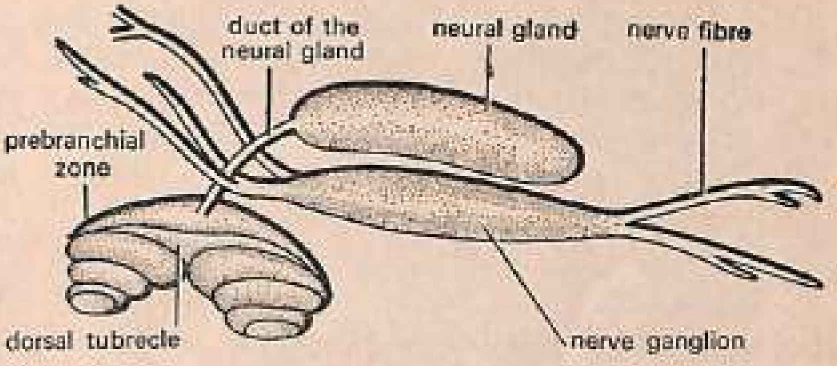


Fig. 2-4. *Herdmania*. Neural complex.

wash, stain in borax carmine, dehydrate and mount in canada balsam.

Characters—Neural complex is composed of neural gland, nerve gland and dorsal tubercle (Fig. 2-4).

[5] *Herdmania*—Spicules

Procedure—Take a piece of test, boil it in KOH, decant, wash, dehydrate and mount in canada balsam.

Characters—Three kinds of spicules are seen in Herdmania, namely pipette-shaped, megascleres and microscleres (Fig. 2-5).

[6] *Herdmania*—Pharyngeal wall

Procedure—Remove the test, cut a piece of pharynx, bleach in chlorinated water so that brownish walls become whitish, stain in borax carmine, dehydrate and mount in canada balsam.

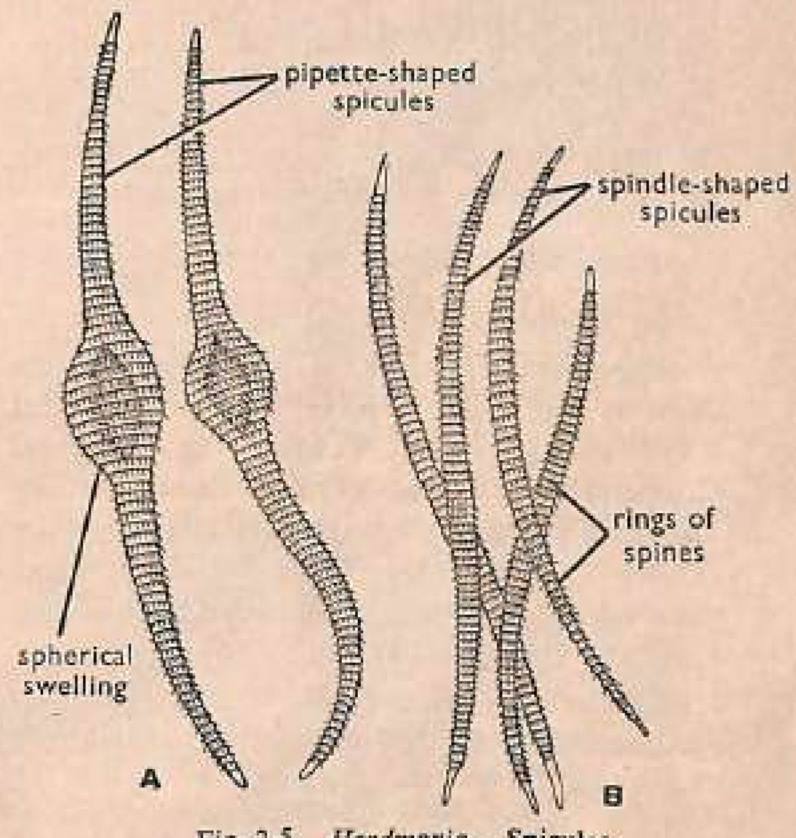


Fig. 2-5. *Herdmania*. Spicules.
A—Pipette shaped. B—Megascleres.

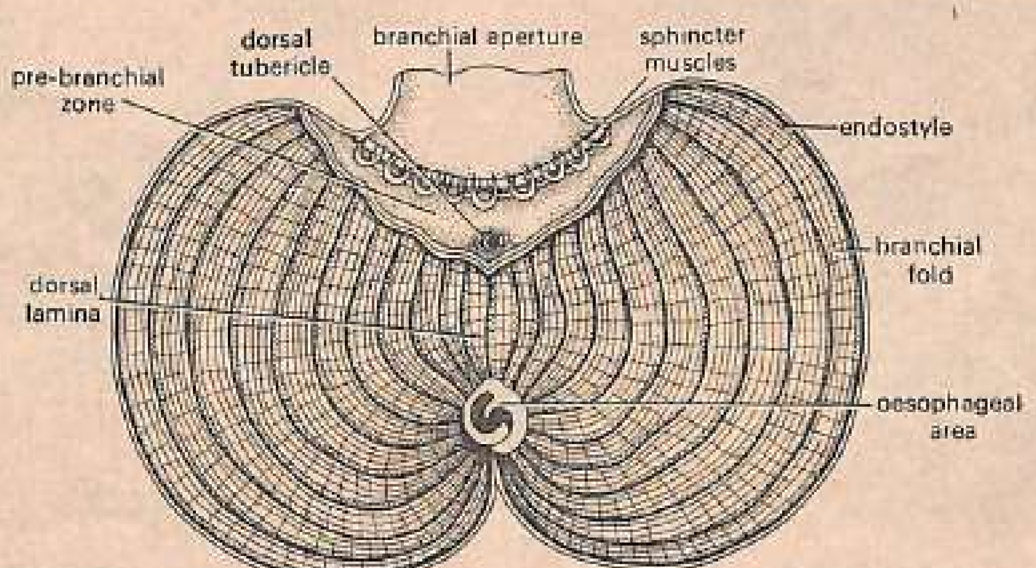


Fig. 2-6. *Herdmania*. Pharyngeal wall.

Characters—(1) The wall is perforated by several pores or stigmata, through which water passes into atrial cavity from branchial cavity. (2) Internally the wall is raised into 9–10 broad, longitudinal folds, which originate from posterior peripharyngeal ciliated bands up to outer margin of oesophagus. (3) The pharyngeal wall is richly vascularised and comprising of internal longitudinal and external transverse vessels. The number of stigmata is about 400,000 (Fig. 2-6).

[7] *Salpa, Doliolum & Amphioxus*

Generally these specimens are preserved in 70 per cent alcohol. For permanent whole mount, wash them in 70 per cent alcohol, stain in borax carmine, dehydrate and mount.

B. FISHES

[8] *Scoliodon*—Placoid scales

Procedure—Take a few small pieces of the skin of scoliodon and boil in 5–10 per cent KOH solution in test tube till skin dissolves. Cool and allow the scales to settle at bottom. Decant KOH and wash the material in water several times to remove KOH. Stain in borax carmine or picro-indigo carmine, dehydrate, clear and mount in balsam.

Characters—(1) Placoid scales or odontoids are minute dermal denticles, closely arranged in regular oblique rows. (2) They form entire exoskeleton of the shark and give a rough appearance to the skin. (3) Each placoid scale comprises of a diamond-shaped, basal plate embedded in the skin and is derived from dermis. (4) Anteriorly the scale has a flat trident spine projecting out of the skin (Fig. 2-7).

[9] *Scoliodon*—Ampullae of Lorenzini

Procedure—Remove a piece of skin around the snout and take out some tissue by forceps and examine it under microscope for above ampullae. Stain in borax carmine, dehydrate, clear and mount in balsam.

Characters—(1) Ampullae of Lorenzini are sensory and mucus-secreting structures. (2) Each ampulla is composed of a tube and 8–9 ampullary chambers consisting of receptor and mucus-secreting gland cells. (3) Receptor cells are innervated by 7th cranial nerve (Fig. 2-8).

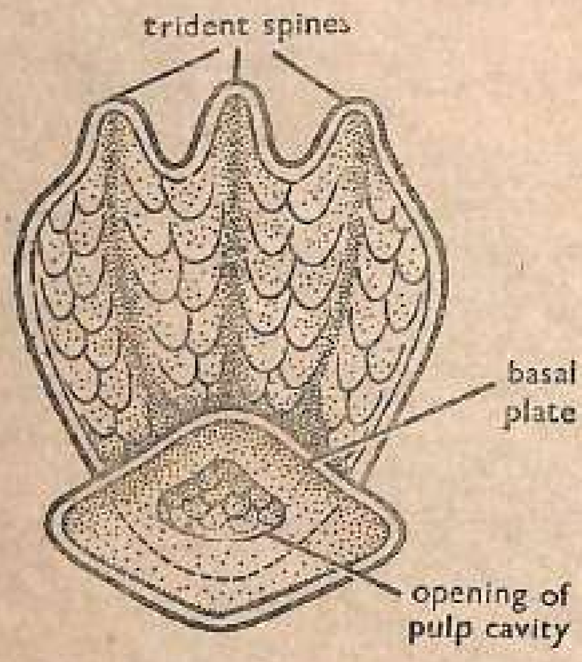


Fig. 2-7. *Scoliodon.* Placoid scale.

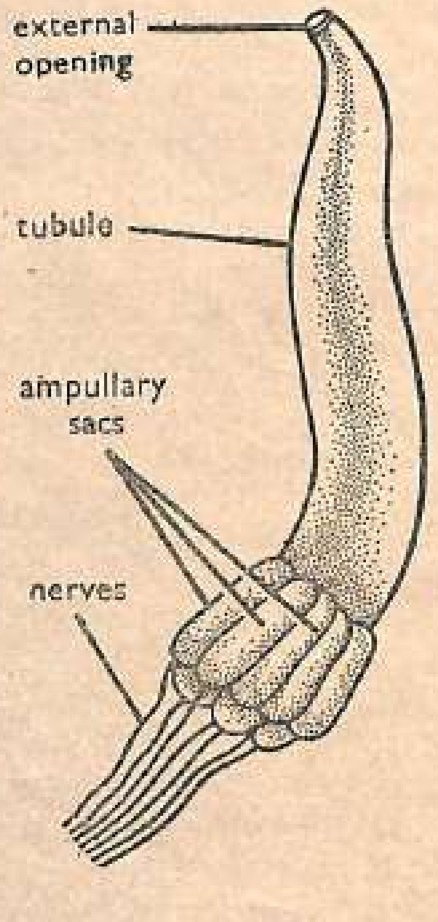


Fig. 2-8. *Scoliodon.* Ampulla of Lorenzini.

[10] *Labeo* (Rohu)—Cycloid scale

Take one or two scales. Stain in picro-indigo carmine, dehydrate and mount in balsam. Each scale consists of lines of growth and nuclues.

[11] *Nandus*—Ctenoid scale

Make permanent mount like cycloid scale. Each scale comprises of several concentric lines of growth, teeth or denticles and nucleus. Ctenoid scales are found in acanthopterygian fishes.

[12] *Lepidosteus*—Rhomboid scale

Take one or two scales from the fish and permanently mount like cycloid scale. Each scale is more or less rectangular in shape, having nucleus and lines of growth (Fig. 2-9).

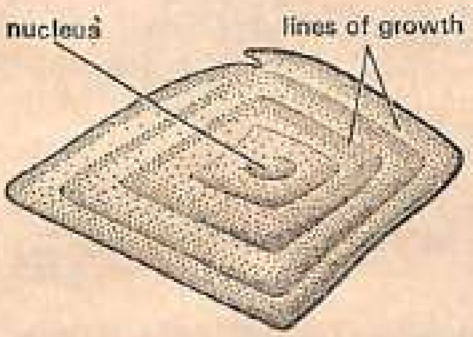


Fig. 2-9. *Lepidosteus.* Rhomboid scale.

C. AMPHIBIA

[13] *Frog*—Blood

Procedure—Take blood from a freshly-killed frog at the edge of a slide. Spread the blood over the slide by the edge of another slide in such a way that a blood film is formed. Dry the blood film, wash, stain in haematoxylin and eosin, dehydrate, clear and mount.

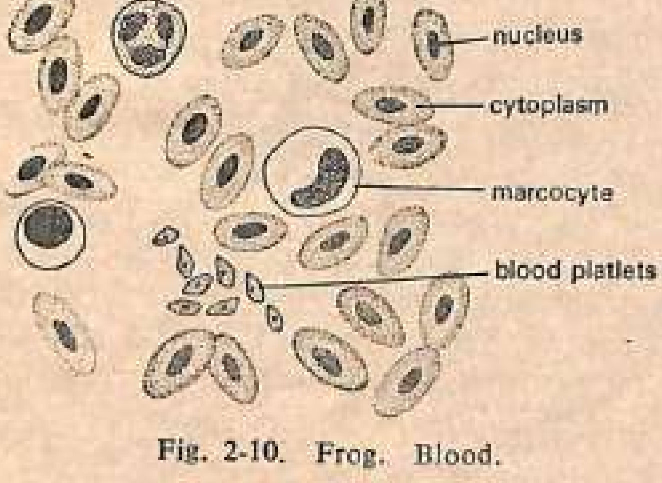


Fig. 2-10. Frog. Blood.

Characters—(1) Blood corpuscles of frog are biconvex and nucleated. (2) In the slide erythrocytes and leucocytes of different kinds are seen (Fig. 2-10).

[14] *Frog*—Squamous epithelium

Procedure—Catch a frog and keep it in a small trough containing water. The water should be just to submerge the frog. After some time, small epidermal cells will be seen which are discarded by the frog. Take 10 flakes of epidermal cells, stain in borax carmine, dehydrate, clear and mount.

Characters—Squamous epithelial cells are thin, flat, polygonal and nucleated (Fig. 2-11).

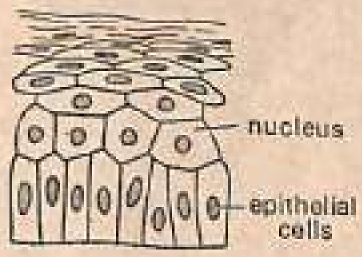


Fig. 2-11. Frog. Squamous epithelium.

[15] *Frog*—Ciliated epithelium

Procedure—Superficially and gently scrap the roof of the mouth of frog by a scalpel and transfer the scraping over a slide or in a test tube. Wash, stain in borax carmine, dehydrate, clear and mount in balsam.

Characters—(1) The ciliated cells are usually columnar in shape. (2) The border of free surface is lined by a bunch of fine tapering vibratile cilia, which during life produce a current in the fluid which covers them (Fig. 2–12).

[16] *Frog*—Columnar epithelial cells

Procedure—Take a small piece of the intestine from a freshly-killed frog and keep the intestine in a solution of one part of methylated spirit and two parts of water for nearly 24 hours. Cut the intestine longitudinally and scrap the internal epithelial lining by a fine and sharp scalpel. Keep the scraping in a staining tube. Stain in borax carmine, pehydrate, clear and mount in canada balsam.

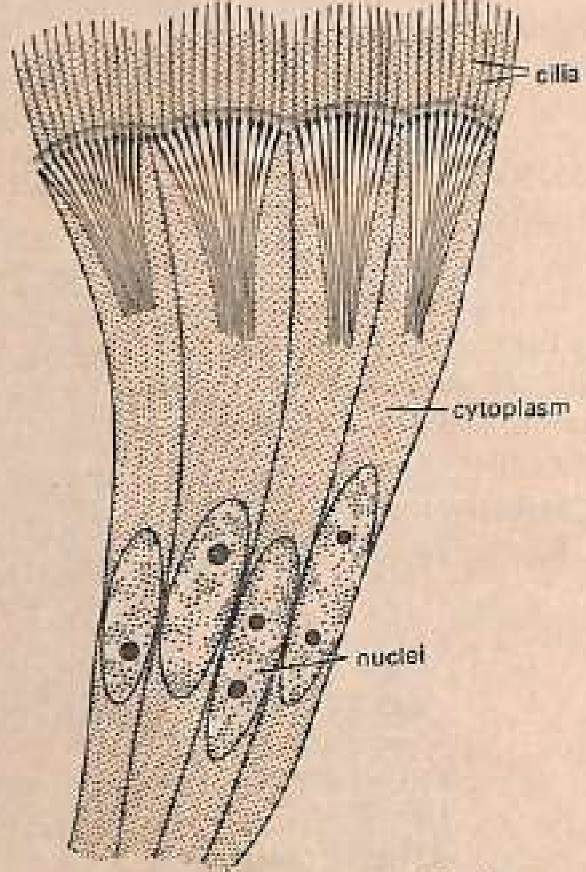


Fig. 2-12. Frog. Ciliated epithelium.

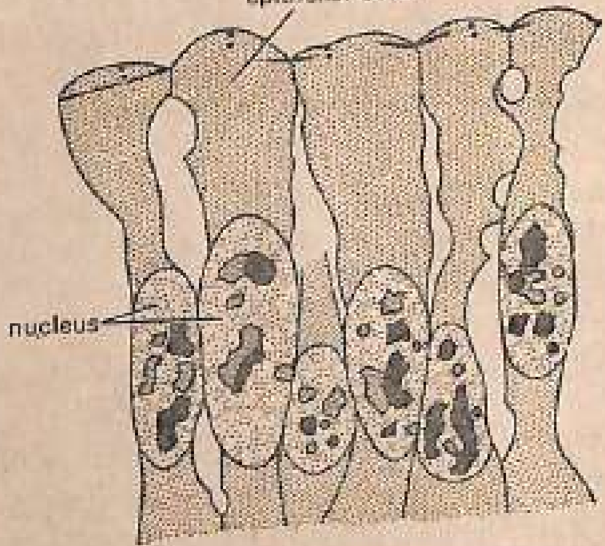


Fig. 2-13. Frog. Columnar epithelium.

Characters—The endodermal columnar epithelial cells are tall, nucleated and granular (Fig. 2–13).

[17] *Frog*—Striated or striped muscle fibres

Procedure—Cut a small portion of thigh muscle of a freshly-killed frog and fix the muscle in corrosive sublimate for 5–10 minutes. Wash the tissue to remove fixative, stain in borax carmine, dehydrate, clear and

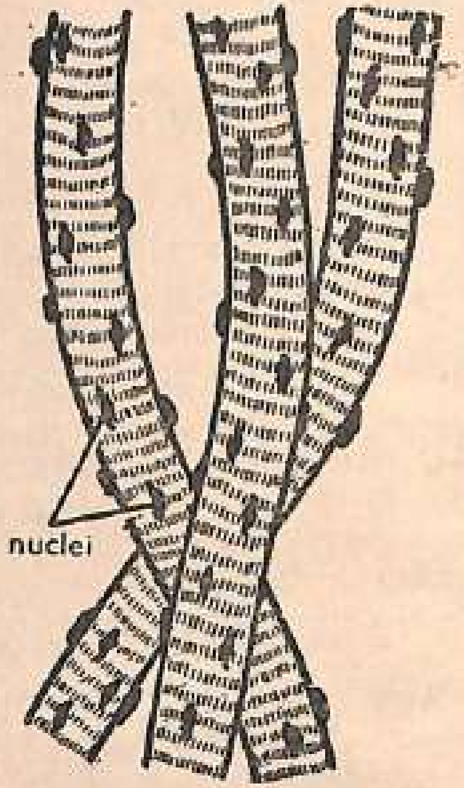


Fig. 2-14. Frog. Striped muscle fibres.

mount in canada balsam. Just before mounting tease the individual muscle fibres with fine needles.

Characters—The striated muscle cell is covered by a delicate membrane called as sarcolemma and is multinucleated. The muscle cell contains dark and light bands (Fig. 2-14).

[18] *Frog*—Unstriated or non-striated or unstriped muscle fibres

Procedure—Take a few fibres of urinary bladder of a freshly-killed frog, fix in corrosive sublimate, wash the fixative, stain in borax carmine, dehydrate, clear, tease and mount in canada balsam.

Characters—Each fibre is uninucleated and without striations (Fig. 2-15).

[19] *Frog*—Columella auris

It is associated with hearing, forming part of middle ear. It is a rod-shaped bone attached with the tympanum. Find the tympanum and cut around it, remove skin and muscles from posterior part of skull, break prootic bone from dorsal side with scalpel or bone cutter to expose the rod-like columella. Its one end is attached with tympanum and other end with the inner wall of cranium through a

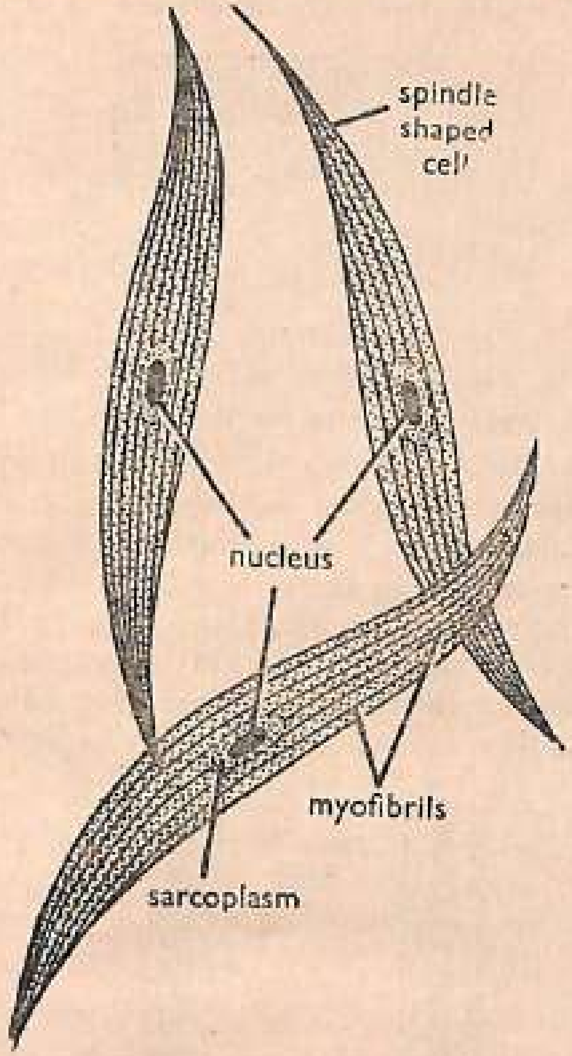


Fig. 2-15. Frog. Unstriped muscle fibres.

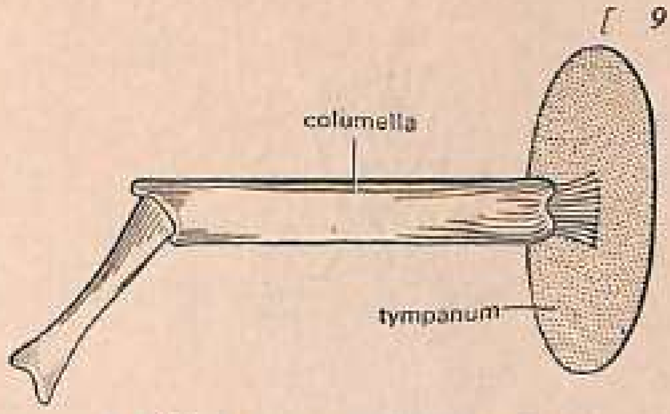


Fig. 2-16. Frog Columella auris.

small rod. Break the prootic bone till entire columella is exposed. Take out the bone, dehydrate and mount without staining or keep in watchglass in water (Fig. 2-16).

D. BIRDS

[20] *Pigeon*—Blood

The method is same as that of frog.

[21] *Pigeon*—Pecten

Procedure—Dissect the eye to remove the eye ball completely and divide it into two halves. One half will contain pecten at the point of entry of the optic nerve. Take out pecten, a brownish structure by forceps, stain, dehydrate, clear and mount in canada balsam.

Characters—It is composed of vertical, vascular and pigmented plates (Fig. 2-17).

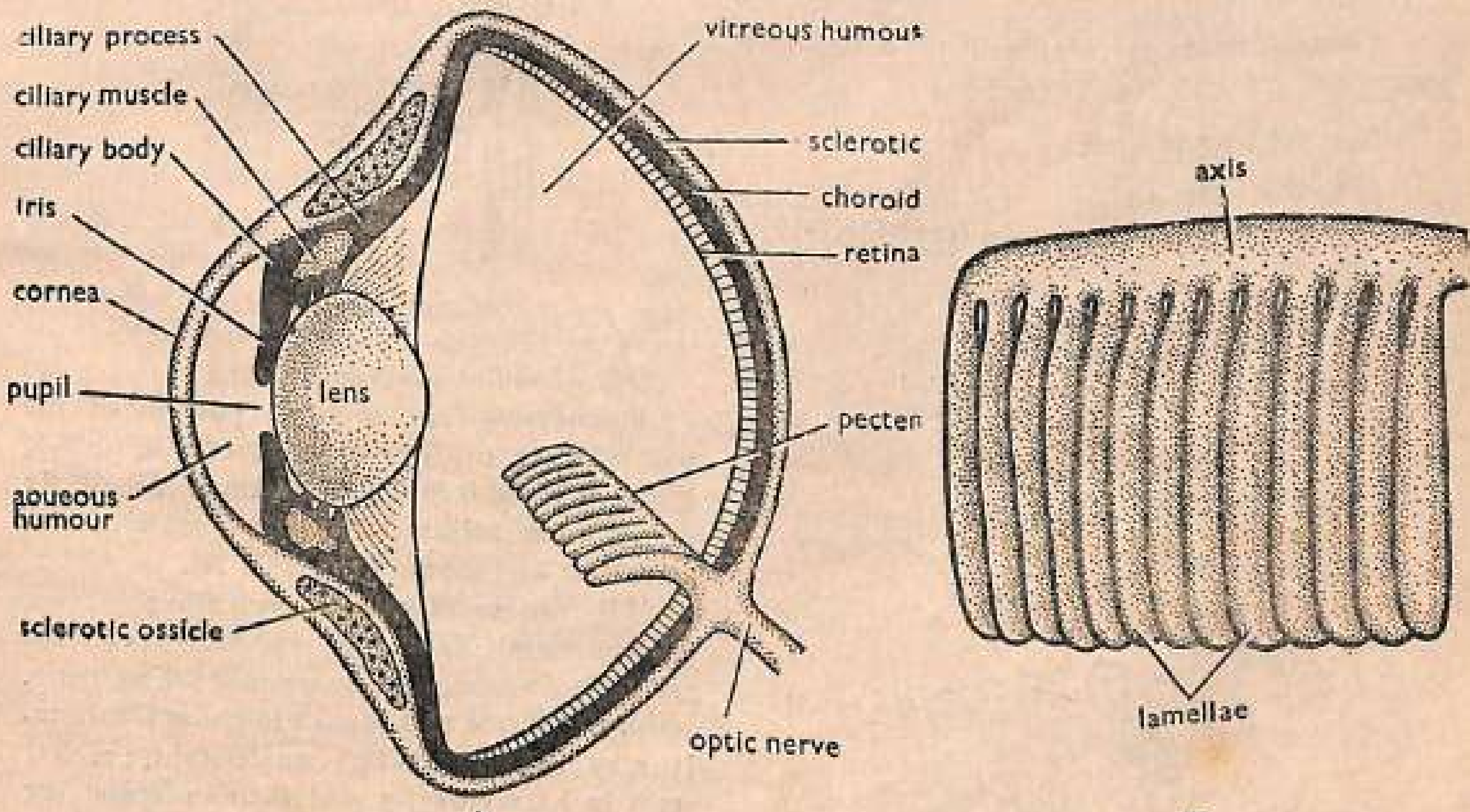


Fig. 2-17. Pigeon. Pecton.
A—Eye showing position of pecten B—Pecten magnified.

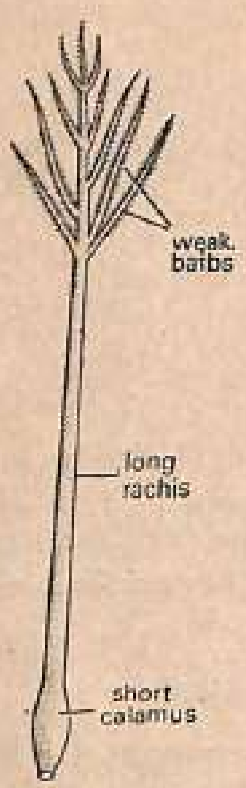


Fig. 2-18. Pigeon. Filoplume.

[22] *Pigeon*—Columella

The procedure is same as in the case of columella of frog.

[23] *Pigeon*—Filoplume

Procedure—Remove all feathers from pigeon and then small hair-like filoplumes are seen. Pluck some of them, fix, stain, dehydrate and mount in balsam.

Characters—It is composed of a hair-like stem and reduced vane (Fig. 2-18).

E. MAMMALS

[24] *Rat*—Blood

Procedure is the same as in frog (Fig.2-19).

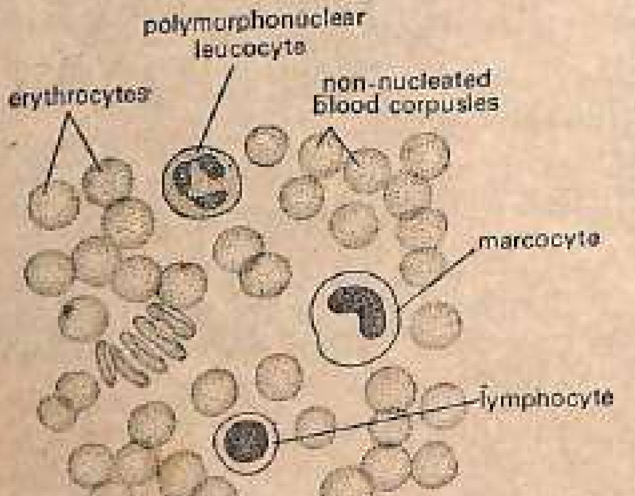


Fig. 2-19. *Rat*. Blood.

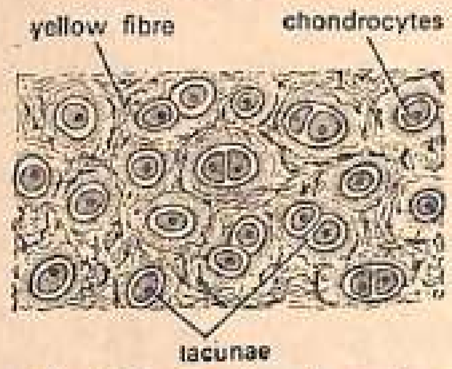


Fig. 2-20. Cartilage in section.

[25] *Cartilage*—T.S.

Procedure—Cut thin hand sections of some cartilage like cranium of dogfish (scoliodon) or cartilaginous caps of humerus and femur. Fix the sections in corrosive sublimate for 2–3 minutes, wash with water, keep in 30, 50 and 70 per cent alcohols, stain in borax carmine, dehydrate, clear and mount in balsam (Fig. 2-20).

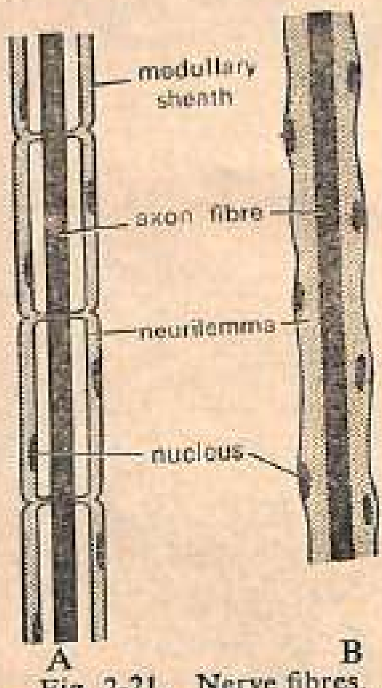


Fig. 2-21. Nerve fibres.
A—Medullated. B—Non-medullated.

[26] *Medullated*—Nerve fibre

Procedure—Take a small portion of the sciatic nerve of frog in normal saline (0·78% NaCl). Tease it to separate small fibres, fix in corrosive sublimate, wash in water, stain, dehydrate and mount (Fig. 2-21 A).

[27] *Non-medullated*—Nerve fibre

Procedure—Take a portion of the sympathetic nerve fibre in normal saline, tease, stain, dehydrate and mount in canada balsam. It may be stained by double stain, i.e. first stain in haematoxylin and then in eosin (see double staining process). (Fig. 2-21 B).

Chapter 3

Museum Specimens

Chordates have countless animals. Only a few amongst many are studied as type specimens. The larger animals are preserved in formalin solution or in 90 per cent alcohol and are kept in almost all museums of Zoology department. The following pages deal with museum specimens of Phylum **Hemichordata** and **Chordata.**

A. MUSEUM SPECIMENS OF PHYLUM HEMICHORDATA

NATURAL HISTORY

Hemichordates are small soft-bodied creatures, living singly or in groups on sandy and muddy sea bottoms or in open sea water. The body and coelom are divided into three regions with paired gill slits and nervous tissue in both dorsal and ventral epidermis. Certain tissue as an anterior projection from mouth cavity was formerly interpreted as a notochord and thus placing this group with **phylum Chordata.** Recent studies **cast doubt** on such interpretation and the **so-called earlier notochord is termed as buccal pouch.** Now this group is placed under **independent phylum Hemichordata.** Between hemichordates and chordates there are resemblances in the pharyngeal gill slits and the collar cord of the nervous system—its origin from dorsal epidermis. The embryo and early larvae of **hemichordates** and **asteroid echinoderms** are much alike in ciliated bands, digestive tracts, form, derivation of anus from blastopore (deuterostome) and enterocoelous coelom. The above features strongly suggest a common origin.

1. *Balanoglossus*

Classification :

Phylum............**Chordata** → Dorsal tubulated nerve cord, gill slits and notochord present.
Subphylum.......**Hemichordata** → Marine, solitary or colonial, enterocoelous and coelomate animals.
Class...............**Enteropneusta** → Several gill slits present and intestine straight.
Type...............(i) *Balanoglossus*—Acorn Worm.
(ii) *Glossobalanus*—Tongue Worm.
(iii) *Saccoglossus*.

Geographical distribution—World-wide or cosmopolitan.

Habit and habitat—It is a marine animal, adapted for burrowing life in the sandy bottom. The animal lives inside the U–tubes—**tubicolous.** Most of them **live in** shallow water but a few go deeper up to 15,000 feet. They burrow slowly by soft proboscis.

Comments :

(1) **Balanoglossus** is commonly called as **"Acorn Worm".**
(2) It measures 1.8 cm. to 2.5 meters.
(3) It is a **bilaterally symmetrical, triploblastic deuterostome** with worm-shaped body, divisible into three regions, anterior **proboscis** or **prosoma,** middle **collar** or **mesosoma** and posterior **trunk** or **metasoma.**
(4) **Proboscis** is conical, **collar** funnel like, while **trunk** is cylindrical.
(5) **Proboscis** contains heart vesicle, central sinus and **buccal diverticulum.** It has thick muscular body wall and its cavity or coelom opens to the exterior by the **proboscis pore.**
(6) **Collar** contains the mouth and **collar coelom** which opens by a pair of collar pores on dorsal surface.

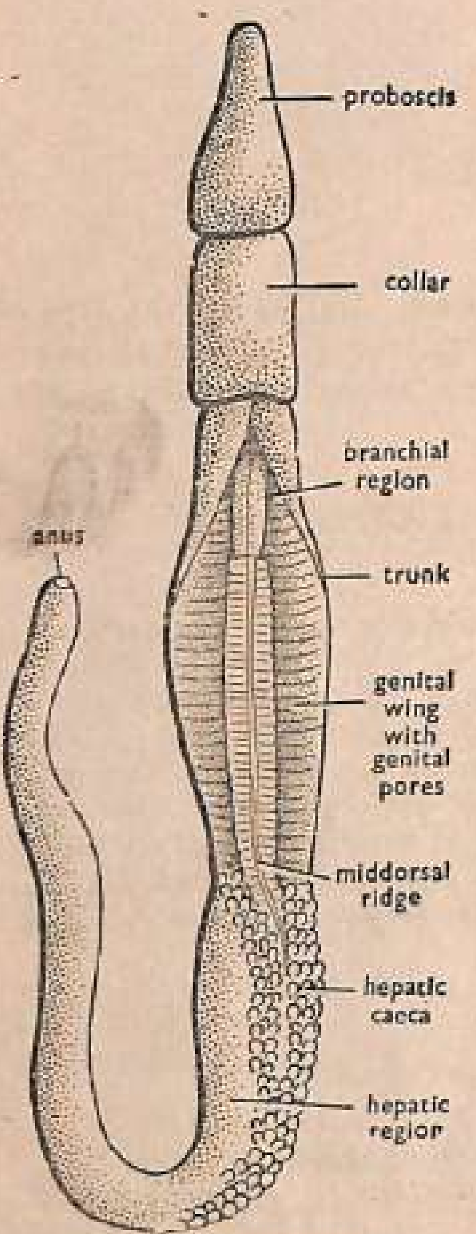


Fig. 3-1. *Balanoglossus.*

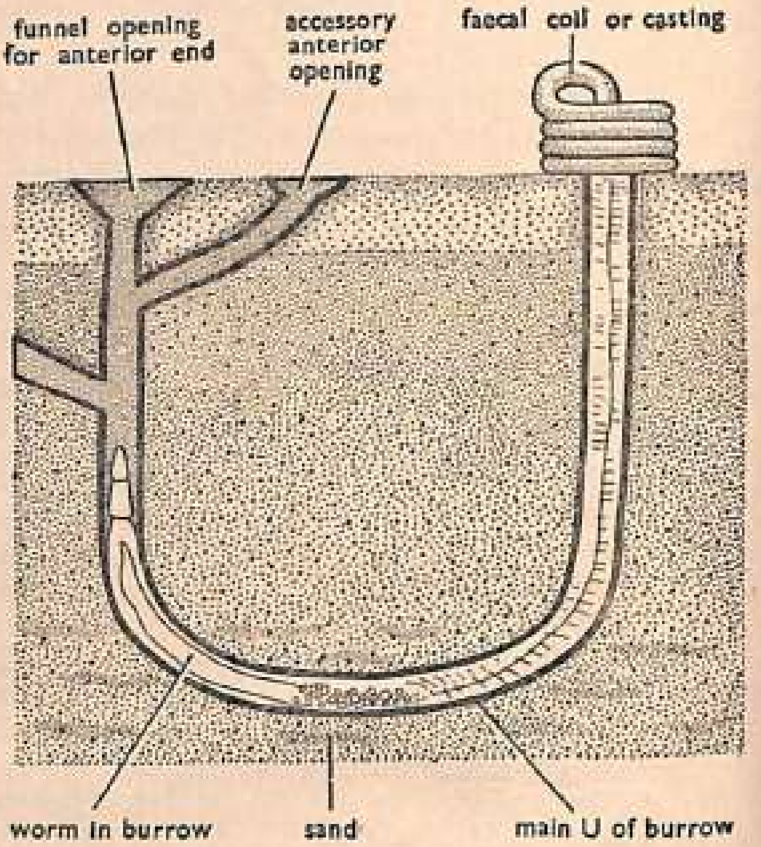


Fig. 3-2. *Balanoglossus* in its tube.

(7) **Trunk** region contains most of the internal organs, such as pharynx, **gonads** or **hepatic region**. Pharynx and gonads constitute **branchiogenital region**, posterior most part in **abdomen.**

(8) The branchiogenital region is composed of (a) **genital wings** having gonads and (b) **branchial** region containing paired gill slits.

(9) **Alimentation** complete and circulatory system usually contains contractile sac or **heart**.

(10) **Sexual dimorphism**. Fertilization external and **development** includes **tornaria** larva. It possesses power of regeneration.

Special feature—Balanoglossus and allied forms have phylogenetic importance. Certain tissue in the form of anterior projection from the mouth cavity was formerly interpreted as a **notochord** and thus placing this group within the Phylum **Chordata**. Recent studies show such structure mainly as **buccal pouch** and now the hemichordates are not included with the chordates but as a separate phylum **Hemichordata.**

Identification—*Short proboscis, gill slits* and *collar*.

2. *Saccoglossus*

The classification, distribution and habits and habitat are same as those of *Balanoglossus*. It can be distinguished from *Balanoglossus* by having much elongated proboscis. *Saccoglossus* is specially found in New Zealand, Australia, Indo-Pacific and Atlantic coasts and North America.

Identification—*Long pointed proboscis.*

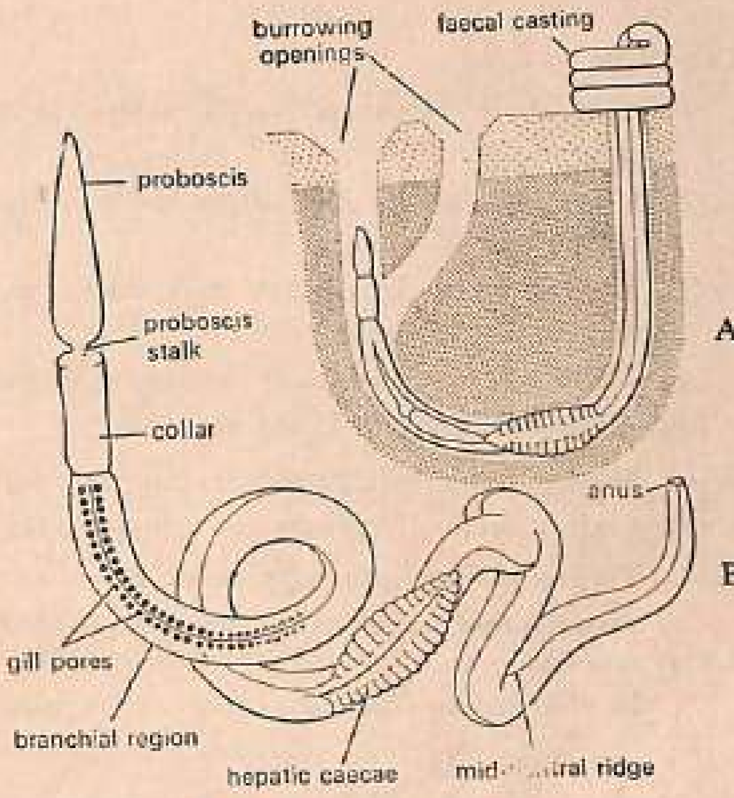


Fig. 3-3. *Saccoglo* *s.*
A—Worm in its burrow.
B—Worm taken out of its burrow.

3. *Rhabdopleura*

Classification :

Phylum.......... ..**Chordata** → Dorsal tubulated nerve cord, gill slits and notochord present.
Subphylum.......**Hemichordata** → Marine enterocoelous coelomate, solitary or colonial.
Class.......... .....**Pterobranchia** → Small hemichordates with cased body.
Order....... ....**Rhabdopleurida**→ Colonial forms with organic continuity and without gill slits.
Type...............*Rhabdopleura*.

Geographical distribution—It is mainly foun d in southern hemisphere especially reported from Norway and Ireland coasts.

Habit and habitat—It is a marine and colonial hemichordate, found 5–50 meters. The colony is formed on hard substratum and also in association with mollusc shells, bryozoans and tunicates.

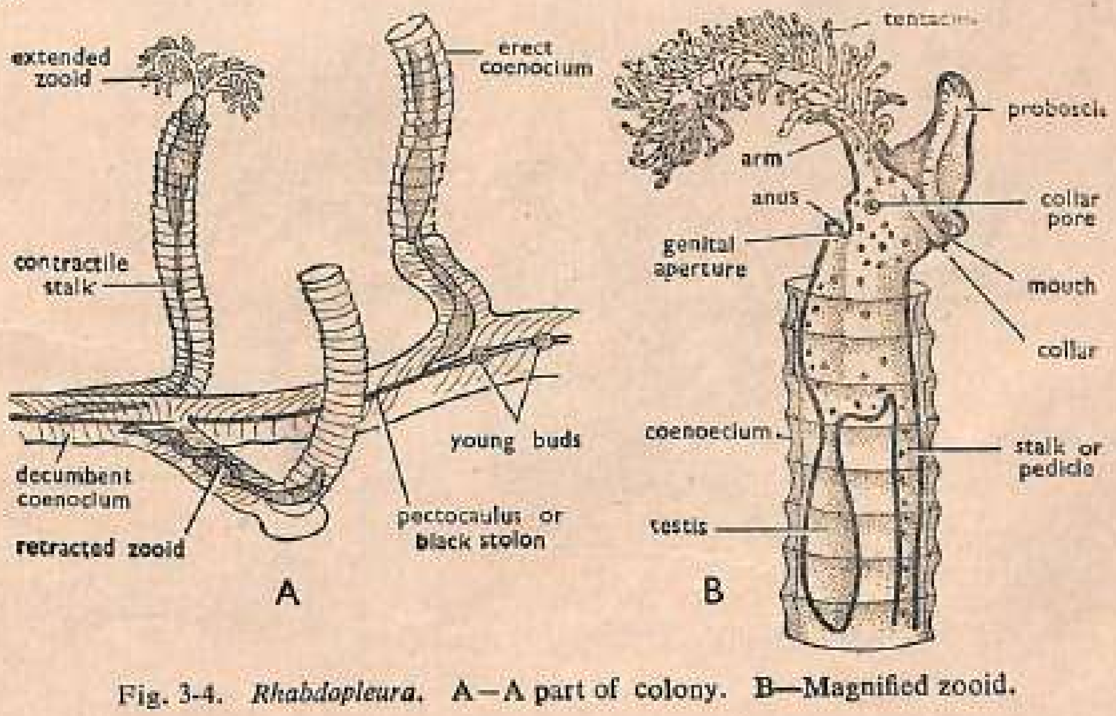


Fig. 3-4. *Rhabdopleura.* A—A part of colony. B—Magnified zooid.

Comments :

(1) The colony consists of **zooids** enclosed into erect tubes which are much more elongated than zooids.

(2) The tube is of creeping nature and is called as **coenoecium** which is secreted and formed by the animal.

(3) Each **zooid** is composed of **stalk, trunk sac, oral lamella, pigment strip, cephalic shield, arms** and **tentacles.**

(4) There is a **lophophore** wit'ı one pair of arms, one gonad, but without gill slits.

(5) **Alimentary** canal is U-shaped.

(6) Most of the zooids are sterile, but male and female specimens may be observed.

(7) Sexes united. Development includes a free-swimming larva.

(8) The zooids are formed by budding.

Special feature—*Rhabdopleura* is a colonial hemichordate with organic continuity between individuals that are produced by asexual budding from one individual.

Identification—*Continuous colony with peculiar shape of zooids.*

4. *Cephalodiscus*

Classification :

Phylum..........**Chordata** → Dorsal tubulated nerve chord, gill slits and notochord present.
Subphylum.....**Hemichordata** → Marine enterocoelous coelomate, solitary or colonial.
Class............**Pterobranchia** → Small hemichordates with encased body.
Order............**Cephalodiscida** → Colonies with gill slits and tentaculated arms.
Type.............*Cephalodiscus.*

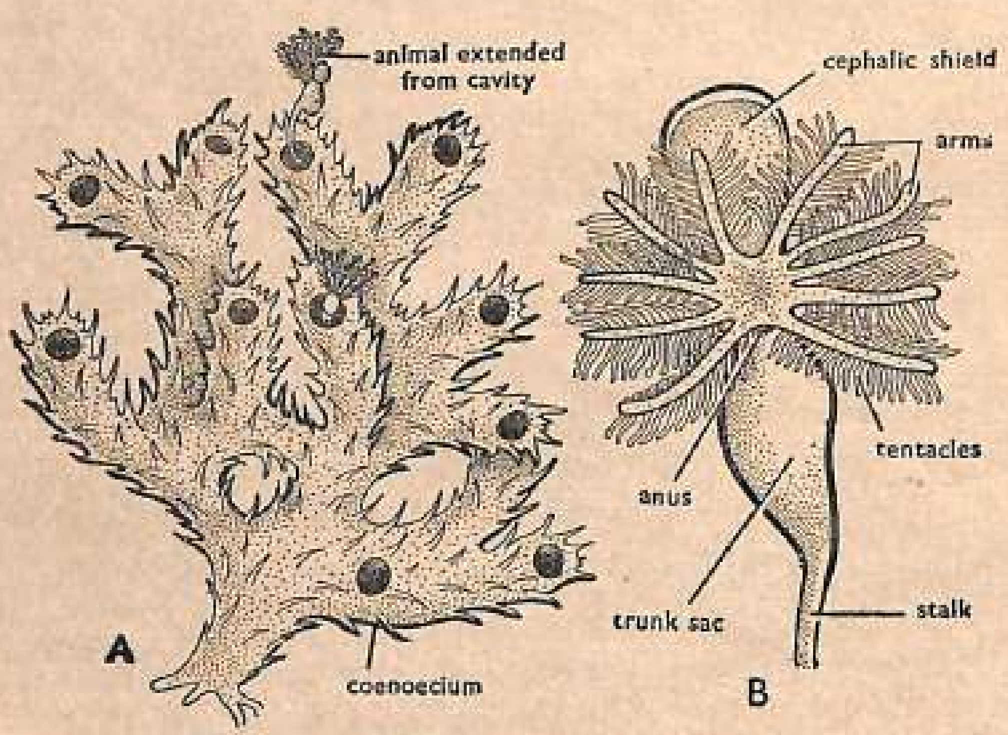


Fig. 3-5. *Cephalodiscus.* A—A part of colony B—One zooid magnified.

Geographical distribution—*Cephalodiscus* is found in antarctic and sub-antarctic regions and restricted to archibenthal and sub-littoral zones. It has been reported from India, Japan, Sweden, Borneo, Malaysia Archipelago and Pacific Ocean.

Habit and habitat—It is a marine colonial animal, found at a depth of 50 to 650 meters.

Comments :

(1) The colony of *Cephalodiscus* is composed of several unconnected animals, or **zooids**, which are enclosed in a common case known as **coenoecium.**

(2) Zooids are microscopic and differentiated into **protosome** or **cephalic shield, mesosome** or **collar** and **trunk.**

(3) The **protosome** is shield-shaped and continuous with collar, which bears two groups of bilaterally arranged **arms** which contain tentacles.

(4) The trunk is divided into anterior sacciform part, containing alimentation and genital organs and posterior slender adhesive stalk.

(5) **Digestive** tube is **U-shaped.**

(6) Breeding seasonal, sexes saparate.

Special feature—Zooids or individuals separate but aggregated into a common housing.

B. MUSEUM SPECIMENS OF PHYLUM CHORDATA

NATURAL HISTORY

Phylum Chordata (Gr. *chorda*=string) comprises **TUNICATES, LANCELETS** and **VERTEBRATES.** The latter includes **lampreys, sharks, rays, bony fishes,** amphibians, **reptiles, birds** and **mammals.** All chordates are bilaterally symmetrical, with 3 germ layers, a segmented body, complete **alimentation** and well-developed coelom. Three **outstanding** characters distinguish them from rest of the animals—a dorsal tubular **nerve cord,** notochord and **gill slits** in pharynx. Chordate remains have not been found in Cambrian rocks. The first vertebrate **groups** are groups of **Silurian** and **Ordovician time.** Thenceforth vertebrates are common and often became dominant elements in the record of animals showing progressive series of developments towards living types. Amphibians probably evolved from crossopterygian fishes in Devonian rocks. Reptiles appeared in Permian and became dominant in Mesozoic era. Birds appeared in upper Jurassic and mammals originated from reptiles in the Triassic period. Phylum Chordata includes a variety of animals, most of them being very economically important, on which animal products industry is dependent such as leather, wool and animal protein. Phylum Chordata has been broadly divided into 3 sub phyla—

(A) Subphylum—**Urochordata** (Tunicates).

(B) **Subphylum—Cephalochordata** (Amphioxus).

(C) Subphylum—**Vertebrates** (lampreys, fishes, amphibians, reptiles, birds and mammals).

SUBPHYLUM UROCHORDATA

NATURAL HISTORY

The urochordates are commonly known as *sea squirts.* The adults do not have notochord and the body is covered with the test containing *branchial* and *atrial* openings. Tunicates inhabit sea from polar oceans to the tropics, mostly in shallow shore water, but some upto depths of 3 miles. Some are free-living, others after a short free-life attach to rocks, shells wharf-piling or ship hulls. They vary in size from microscopic to a foot in diameter. Variously coloured forms are found. They have about 2000 species, of which 100 are pelagic. Reproduction is sexual or asexual. The group name refers to the self-secreted "tunic" or sac-like covering over the body. The best known tunicates are sea squirts or ascidians.

Outline Classification of Tunicates

Urochordata is divided into three classes.

Phylum................Chordata
Subphylum..........Urochordata
Class 1.................Ascidiacea
Order 1...............Enterogona
Types—Clavelina, Ascidia, Ciona, etc.
Order 2....... ......Pleurogona
Types—Botryllus, Herdmania, Molgula, etc.
Class 2................Thaliacea
Order 1...............Pyrosomatoida
Type—Pyrosoma.
Order 2...............Doliolida
Type—Doliolum.
Order 3...............Salpida
Type—Salpa.
Class 3................Larvacea
Order...................Copelata
Types—Oikopleura, Tectillaria, etc.

5. *Ascidia*

Classification :

Phylum.........**Chordata** → Dorsal tubulated nerve cord, gill slits and notochord present.
Subphylum.....**Urochordata** → Marine. Test containing tunicin and chordate characters only found in lar
Class............**Ascidiacea** → Marine, solitary or colonial, bottom-dwelling specimens.
Order..... .....**Enterogona** → Neural gland ventral to nerve cord.
Type............*Ascidia.*

Geographical distribution—*Ascidia* is commonly found in cold temperate regions.

Habit and habitat—*Ascidia* is a solitary, marine and sedentary urochordate inhabiting shallow water but some occur down to 2,900 fathoms.

Comments :

(1) Ascidians are commonly called as **sea squirts.**

(2) The shape of the body is short and cylindrical with a broad base attached to rocky substratum.

(3) The test is translucent, wrinkled and brownish in colour.

(4) Anteriorly body contains eight-lobed terminal **branchial siphon** and sub-terminal six-lobed **atrial siphon**. **Mouth** and **cloaca** are found in branchial and atrial siphons respectively. Mouth is surrounded by 50–100 tentacles.

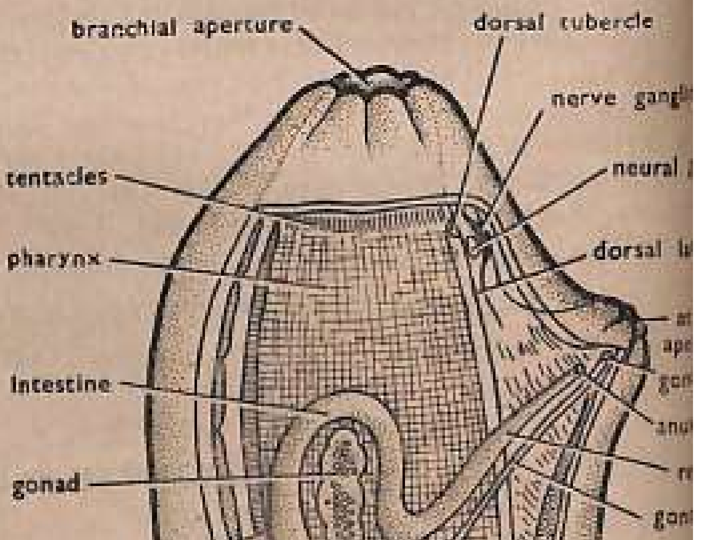


Fig. 3-6.
Ascidia partly dissected to show internal anatom

(5) Branchial siphon leads into **pharynx** which is perforated by stigmata.
(6) Dorsal tubercle is separated from the nerve ganglion and dorsal lamina is membranous.
(7) **Stomach** with smooth wall and left side of pharynx is occupied by bent pharynx.
(8) Excretory organs are renal vesicles. Anus is double lipped.
(9) Monoecious. Ovary, testes in the same animal. Reproduction sexual. Metamorphosis retrogressive.
(10) Oviparous.

Special feature—There are some **compound ascidians** in which individuals are buried in a common test. The development includes tailed larva exhibiting typical chordate characters having notochord and nerve cord, etc. **Kowalewsky** (1886) carefully studied the development of larval ascidians and brilliantly demonstrated true position of the group among chordates. Compound ascidians reproduce asexually by gemmation and also produce eggs and sperms for sexual reproduction.

Identification—*By lobed siphons.*

6. *Ciona*

Classification :

Phylum........**Chordata** → Dorsal tubulated nerve cord, gill slits and notochord present.
Subphylum...**Urochordata** → Marine. Test containing tunicin and chordate characters only found in larva.
Class.........**Ascidiacea** → Marine, solitary or colonial, bottom-dwelling specimens.
Order.........**Enterogona** → Neural gland ventral to nerve cord.
Type...........*Ciona.*

Geographical distribution—*Ciona* is commonly found in western sea waters.

Habit and habitat—It is a solitary and sedentary animal found in shallow waters attached with rocks.

Comments :

(1) Animal resembles with *Herdmania* and measures 9–12 cm. in length.
(2) Body of the animal is cylindrical, tubular, transparent and longer than breadth.
(3) It contains 8-lobed **branchial opening** and 6-lobed **atrial** opening anteriorly.
(4) Body is covered by a transparent **test** and through the test thick longitudinal **muscle** bands can be seen.
(5) The **alimentation** is complete U-shaped and consists of pharynx, oesophagus, stomach and intestine and it lies in the **epicardial cavity**. The different parts of gut occupy the same topographical parts as that in *Herdmania.* The gill slits are rectangular. The **dorsal tubercle** is horseshoe shaped. **Intestine** contains **typhlosole.** Running

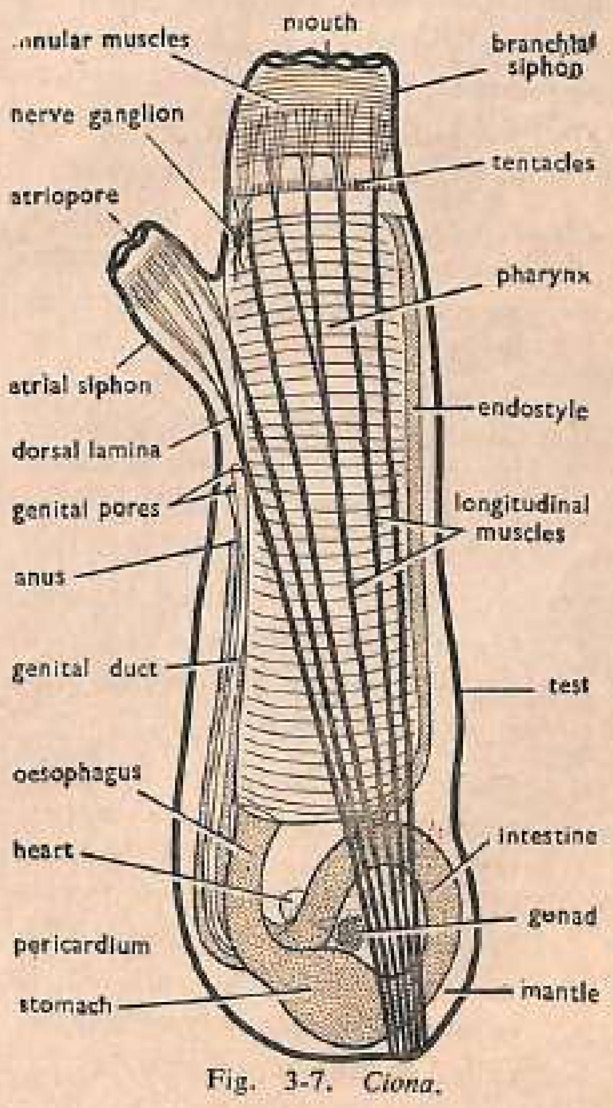


Fig. 3-7. *Ciona.*

parallel with the **endostyle** are right and left ciliated bands which continue posteriorly as **retropharyngeal bands.**

(6) The gonads lie in the loop of intestine. Ovary is compact and testis branched. Longitudinal muscle bands are clearly seen.

Special feature—*Ciona* is hermaphroditic and protogynous. The blood of *Ciona* is rich in a green pigment, called as **haemovanadin**, containing **vanadium** produced by **vanadocytes**. The pigment probably does not take part in oxygen transport. *Ciona intestinalis* is common species.

Identification—*By thick longitudinal muscle bands.*

7. *Herdmania*

Classification :

Phylum........**Chordata** → Dorsal tubulated nerve cord, gill slits and notochord present.
Subphylum...**Urochordata** → Marine, test containing tunicin and chordate characters are only found in larva.
Class..........**Ascidiacea** → Marine, solitary or colonial, bottom-dwelling animals.
Order..........**Enterogona** → Body undivided and neural gland dorsal to nerve cord.
Type...........*Herdmania*.

Geographical distribution—Different species of *Herdmania* (*Rhabdocynthia*) are widely distributed in the Pacific, Atlantic and Caribbean seas, besides Indian Ocean.

Habit and habitat—*Herdmania* is solitary, sedentary and sometimes living as commensal in association with gastropod shell, specially over *Xancus pyruns* (Shankh) and *Xancus angulatus* (Conch).

Comments :

(1) *Herdmania* is commonly called as **Monoascidian** or **Sea squirt.**

(2) *Herdmania* is more or less like a purse or a large oval potato, measuring 6·5 to 11·8 cm. in length and 5·2 to 6·9 cm. in breadth.

(3) Body is dark brown, reddish brown, yellowish brown in colour and regionated into body proper and **foot.**

(4) **The foot** is large, dirty, rough, leathery and with a number of foreign objects. It forms one-third of the body.

(5) Body is enclosed in a thick, tough and supporting transparent test. Test or tunic is in the form of thick translucent protective investment meant for respiration and reception of stimuli. It is composed of polysaccharide, called as **tunicin** and protein.

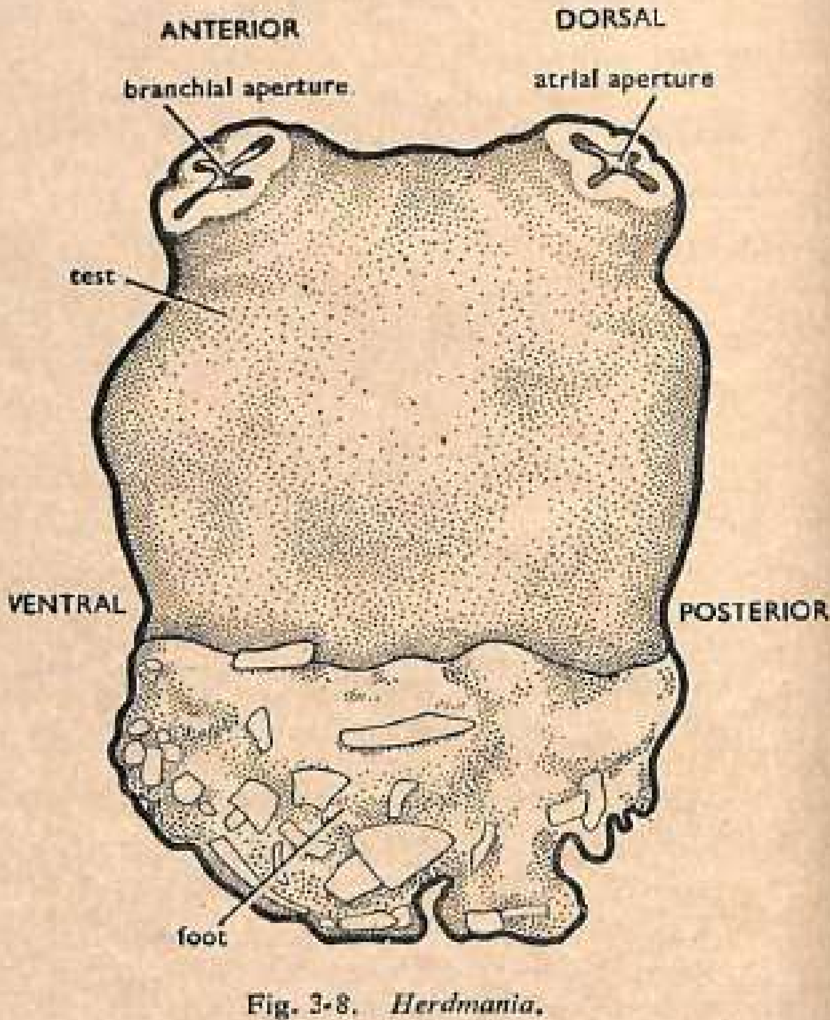


Fig. 2·8. *Herdmania.*

(6) Without cutting the animal open at the free end, body is drawn to form 1·5 cm. long **branchial** or **incurrent siphon** and 1·0 cm. long **atrial** or **excurrent siphon**. The incurrent opening or **mouth** is laterally placed, while the excurrent opening is directed upwards.

(7) Body proper lies within test. After removing the test, body is oriented by the intestinal **loop.** Thick **longitudinal** and **circular** muscles are found around siphons. On left side are **stomach**, loop of **intestine**, left lobe of **liver** and left **gonad**. On right side, besides liver and gonad, there is a thin tubular **pericardium** and a knob-like **neural complex**.

(8) *Herdmania* is **hermaphroditic** and **protogynous**.

(9) Fertilization external. The development includes a fully formed larva called as **ascidian tadpole** larva. It contains all the chordate characters **i.e.** notochord and nerve chord, etc.

(10) Metamorphosis is retrogressive.

Special feature—Herdmania in adult form is devoid of any chordate characters. Its chordate features are exhibited only by its tadpole larva. *Herdmania* has also a peculiar symmetry, branchial aperture marks in **anterior end** and opposite end is the **posterior end**. The atrial aperture indicates **dorsal side** and the area diagonally opposed to it represents ventral side. Such abnormal symmetry is brought about by **metamorphosing** larva into sedentary adult.

Identification—*By siphons* and *symmetry*.

8. *Pyrosoma*

Classification :

Phylum... ....**Chordata** → Dorsal tubulated nerve cord, gill slits and notochord present.

Subphylum...**Urochordata** → Marine, test containing tunicin and chordate characters are only found in larva.

Class..........**Thaliacea** → Free-living, pelagic, solitary or colonial. Budding and alternation of generations common.

Order........**Pyrosomatida** → Colonial forms, having zooids like ascidia.

Type..........*Pyrosoma*.

Geographical distribution—*Pyrosoma* is distributed in tropical and subtropical regions.

Habit and habitat—*Pyrosoma* is pelagic, marine, colonial and bioluminescent urochordate, found at a depth of 500 meters. A few forms are abyssal.

Comments :

(1) It is a thimble-shaped **hypopleustonic** colony measuring 2·5 cms. to 1 meter in length and consists of several individuals, called as blastozooids, embedded in a common test.

(2) **Branchial** and **atrial** openings are at opposite ends.

(3) The branchial openings or mouths of individuals or zooids open to the outside, while **atria** open into a common cloaca with a terminal outlet, from which a continuous **jet** emerges.

(4) The colony moves by **a jet propulsion**.

(5) Each **zooid** consists of a large **branchial sac** with **endostyle** and **dorsal lamina**, **neural complex**, **heart** and **atrium**.

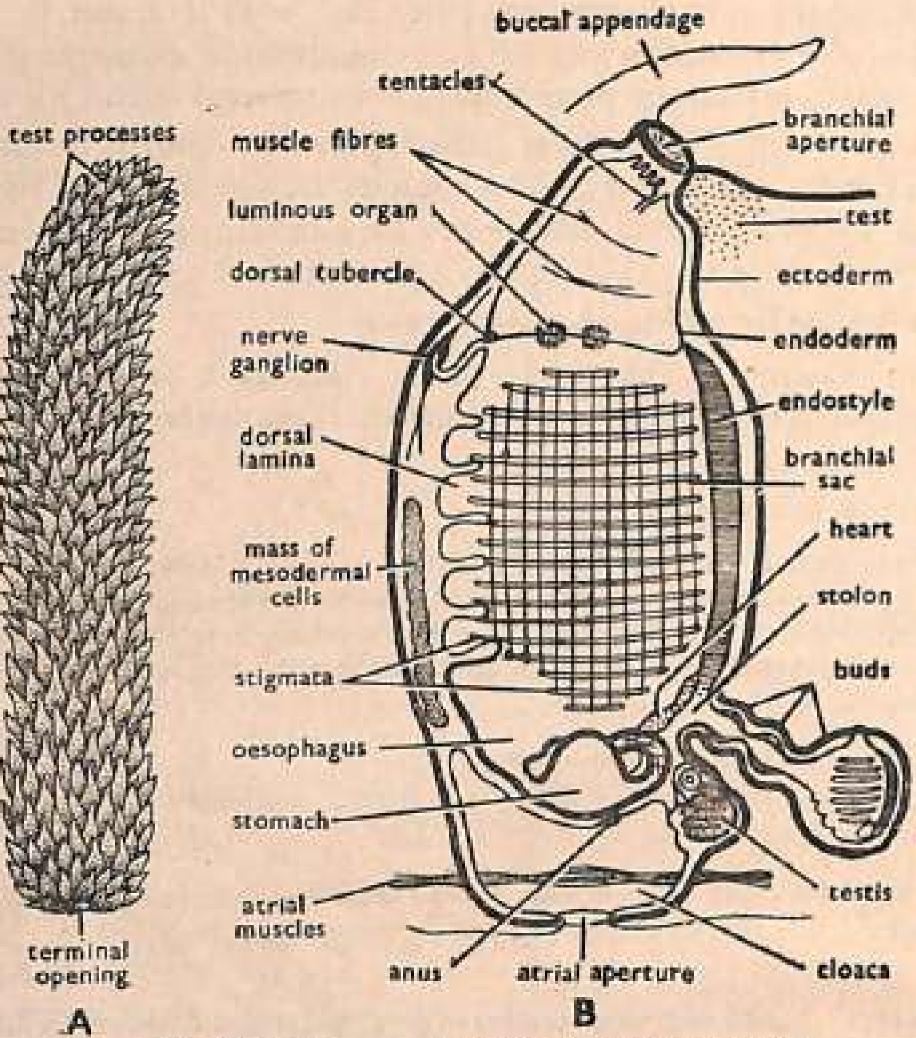


Fig. 3-9. *Pyrosoma*. A—Colony. B—A single zooid.

(6) Branchial sac contains 50 **gill slits** divided by internal longitudinal **bars**. Endostyle communicates with **peripharyngeal band**, **retropharyngeal band** and **dorsal lamina**. **Intestine** makes a loop around stomach and ends into **atrium**. **Heart** is ventral. Lobed **testis** is found behind **ovary**.

(7) Close to the mouth of each zooid arises a tongue-like process of the test, called as **buccal appendage**.

(8) Hermaphroditic. Reproduction **sexual** and **asexual**.

(9) A single fertilized egg develops within **blastozooid** and gives rise to asexual **oozooids**. Oozooid gives stolon that forms 4 **ascidiozooids or tetrazooid** which degenerates and gives rise to **cyathozooid**. The latter is enclosed in a test and by repeated budding forms a colony.

(10) Asexually colony multiplies the number of zooids by direct stolon **budding**, producing **blastozooids**.

Special feature—The most **outstanding** characteristic of the creature is the shining of powerful **light** without heat, a phenomenon called as **bioluminescence**. Animal produces **light** on stimulation and when all colonies produce light, the entire area is illuminated and one can read books. The light is produced by **bioluminescent cells**, which contain curved inclusions. According to some, these bioluminescent cells contain luminescent symbiotic bacteria. However, in any case, **light** is emitted by the **chemical interaction** between two compounds, **luciferin** and **luciferase**, in the presence of moisture.

Identification—*By opposite branchial and atrial siphons with thimble-shaped colony and buccal appendage.*

9. *Doliolum*

Classification :

Phylum............**Chordata** → Dorsal tubulated nerve cord, gill slits and notochord present.
Subphylum.......**Urochordata** → Marine, test containing tunicin and chordate characters are only found in larva.
Class..............**Thaliacea** → Free-living, pelagic, solitary or colonial. Budding and alternation of generations common.
Order..............**Doliolida** → Complete ring of muscle bands or cyclomyaria present.
Type...............*Doliolum*.

Geographical distribution—*Doliolum* is distributed in tropical and subtropical surface water.

Habit and habitat—*Doliolum* is a marine, pelagic, free-living and **solitary tunicate** swimming by forcing water out of atrium after each powerful muscle contraction.

Comments :

(1) *Doliolum* is commonly called as **chain tunicate**. It measures 1–1·5 cm.

(2) It shows **polymorphism**. It exists in two **phases** : (a) **gonozooid** or **solitary** phase, and (b) **oozooid** or gregaria phase.

(3) **Oozooids**—These exhibit the following characters :

I. Fully grown **oozooid** has a **barrel-shaped transparent** body with large **mouth** or **branchial** and **atrial** apertures.

II. The edges of the above lobes contain **sensory lobes**—10 on branchial and 12 on atrial side.

III. There are **9 complete muscle bands.**

IV. Mouth leads into **pharynx** with a few **stigmata**. It has ventral **endostyle, retropharyngeal** and peripharyngeal bands.

V. Dorsal lamina absent.

VI. **Viscera** consists of **oesophagus**, **stomach**, **intestine**, **digestive gland**, heart and **neural complex**.

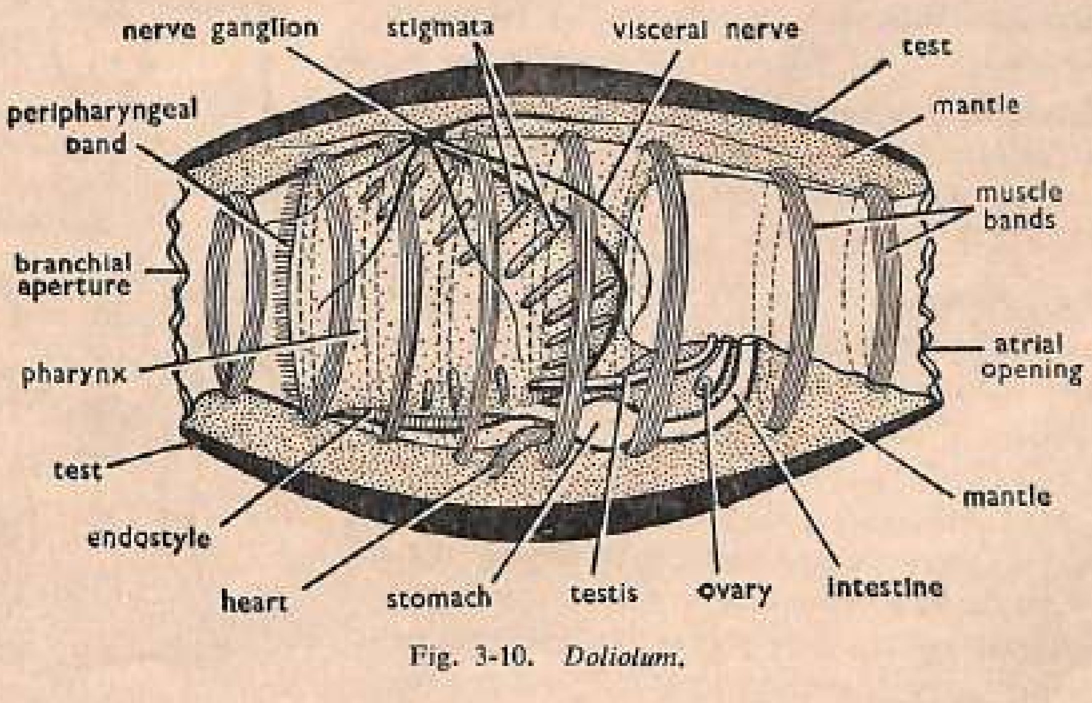


Fig. 3-10. *Doliolum*.

VII. Mid-pharynx has sensory **otocyst**.

VIII. **Oozooids** reproduce asexually by **stolon budding**. *Pharynx gives a ventral* **stolon** *from where* **pro-buds** *arise which reach upto cadaphore* and *dorsal stolon. Each pro-bud divides to form definitive buds which are arranged on cadaphore in 2 lateral and 2 median rows. They reorganize* into 3 kinds of zooids :

(a) **Gastrozooids**—with gill slits for feeding.

(b) **Phorozooids**—with muscle bands for propelling.

(c) **Gonozooids** are reproductive sexually. The last 2 detach and set free. **Gonozooids** develop gonads and carry out reproduction.

(4) **The gonozooid** can be differentiated from oozooid in having 12 and 10 sensory lobes in **branchial** and **atrial** openings, 8 **muscle bands**, **cadaphore** and **otocyst** absent and with **testis** and **ovary**.

Special feature—**Doliolum** is favourite tunicate. The development includes tailed larva which metamorphoses into oozooids.

Identification—*By muscle bands numbers.*

10. *Salpa*

Classification :

Phylum.........**Chordata** → Dorsal tubulated nerve cord, gill slits and notochord present.

Subphylum.....**Urochordata** → Marine, test containing tunicin and chordate characters are only found in larva.

Class............**Thaliacea** → Free-living, pelagic, solitary or colonial. Budding and alternation of generations common.

Order...........**Salpida** → Pelagic. Incomplete muscle bands.

Type............*Salpa*.

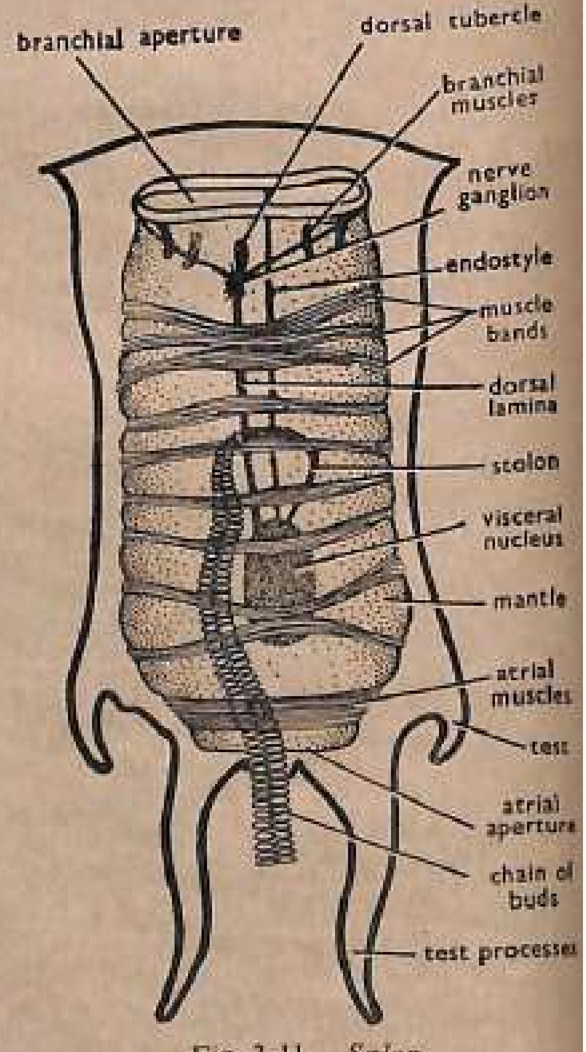


Fig. 3-11. *Salpa*.

Geographical distribution—*Salpa* is commonly found in tropical waters.

Habit and habitat—Salpians are highly modified and peculiar tunicates, living in open sea with specialized reproduction. They are found on surface and down to depths of 200 meters.

Comments :

(1) The body of the animal is cask-shaped, measuring 1–8 cm. in length and covered by a thick test.

(2) *Salpa* also exhibits polymorphism and it exists in two phases—(a) **oozooid** or **asexual phase**, and (b) **blastozooid** or **sexual phase** or aggregate type. The two phases are very much alike, but oozooids are smaller in size and having lesser number of muscle bands. Sexually produced **Salpa** is called as **solitary type** or **oozooid**, while alternate generation produced by budding is called as **aggregate** type or **blastozooid**.

(3) The typical **oozooid** consists of **branchial** and **atrial** openings at opposite ends. A ciliated funnel is present on dorsal side. **Nerve ganglion, sub-neural gland, dorsal lamina** and pharynx which has endostyle, **peripharyngeal** and **retropharyngeal** bands and single pair of gill slits.

(4) The **pigmented eyes** have been reported in most of the forms.

(5) The **oesophagus, stomach, intestine** and **gonad** constitute a **compact** mass along the postero-ventral side which is called as **nucleus.** Muscle bands incomplete.

(6) A stolon originates from ventral side and it carries endostylic and mesenchymal extensions. The stolon produces buds or **blastozooids.**

(7) **Blastozooid** is a sexual phase, having paired testes and a single ovary.

(8) **Blastozooid** is **protogynous** and the fertilization is internal. The ovum gives rise to a single **oozooid.**

(9) The free oozoid is larger and bigger in size but remains **sexless.** The stolon in it grows out as a long rope between **heart** and **endostyle.**

(10) About 50 to many zooids are formed. These zooids develop gonads and become **blastozooids.**

Special feature—Sexual and asexual generations alternate. The important character of the animal is locomotion by propelling mechanism in which active muscle bands contract and inturned water is ejected.

Identification—*By incomplete muscle bands.*

11. *Oikopleura*

Classification :

Phylum........**Chordata** → Dorsal tubulated nerve cord, gill slits and notochord present.
Subphylum...**Urochordata** → Marine, test containing tunicin and chordate characters are only found in larva.
Class..........**Thaliacea** → Free-living, pelagic, solitary or colonial. Budding and alternation of generations common.
Order..........**Larvacea** → Minute neotenous tunicates.
Type..........*Oikopleura.*

Geographical distribution—*Oikopleura* is widely distributed in open sea.

Habit and habitat—*Oikopleura* lives in upper levels of the sea and swims by contractions of the bent tail. Some are brilliantly **pigmented** (coloured) with orange or violet and when abundant, may colour the water. It is a **neotenous** and **planktonic** tunicate.

Comments :

(1) *Oikopleura* is minute, microscopic and larva-like in appearance with a persistent notochord measuring about 2 mm.

(2) The animal lives in a "**house**" made by secretion from a special part of the skin, called as **oikoplastic epithelium.**

(3) The body narrows towards mouth and expands posteriorly dorsoventrally. The caudal appendages have undergone torsion of 90°.

(4) The tail is a broad structure, which rests at an angle to the rest of the body.

(5) The movement of the tail produces water current. The food particles are filtered by an elaborate arrangement in the house. The water enters into house by a pair of posterior **filtering windows** and is passed through filter pipes in front of mouth. Minute flagellates are sucked by mouth.

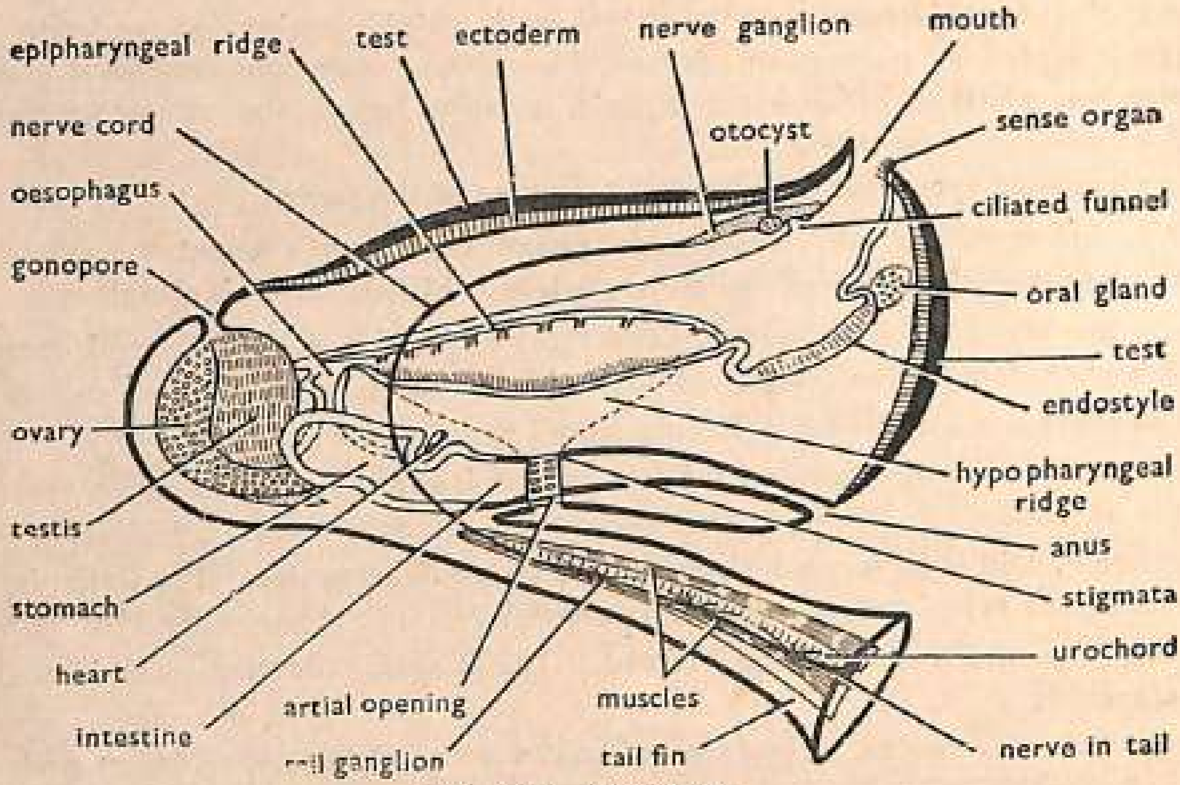


Fig. 3-12. *Oikopleura.*

(6) Dorsal lamina and tentacles are absent.

(7) Mouth leads into **alimentation** comprising of **pharynx, oesophagus, stomach** and **intestine**. Pharynx has gill slits opening to outside, **peripharyngeal** band, **retropharyngeal** band and **endostyle**.

(8) **Protandrously hermaphroditic.** Testes two, kidney shaped. Left testis encloses **ovary.**

(9) Internal space filled by **haemocoelomic lacunae** having blood circulation by a transparent heart.

(10) **Tail** has **notochord, nerve cord,** broad fin and 7–12 striped muscle cells.

Special feature—The general structural organization resembles with a typical ascidian tadpole and it can be very safely concluded that these forms have arisen from tunicates by the acceleration of the rate of development of alimentation and reproductive systems, so that the metamorphosis and the adult stage are omitted and it shows phenomenon of **neoteny** or **paedomorphosis.**

Identification—*By test and tail.*

C. MUSEUM SPECIMENS OF CEPHALOCHORDATA

Cephalochordata includes first chordate, rather generalized chordate. Cephalochordata includes a single specimen, called as *Amphioxus lanceolatus*, **Yarrel** (1836). **Costa** (1834) gave the name *Branchiostoma.*

12. *Branchiostoma Lanceolatum or Amphioxus Lanceolatus*

Geographical distribution—Widely distributed in temperate and tropical seacoasts. *Branchiostoma virginea* occurs from Chesapeake Bay to Florida and *B. californiensis* from San Diego Bay southward.

Habit and habitat—*Amphioxus* burrows in clean shifting and shallow shore waters leaving only its anterior end protruded. At times, animal emerges to swim by rapid lateral movements of the body.

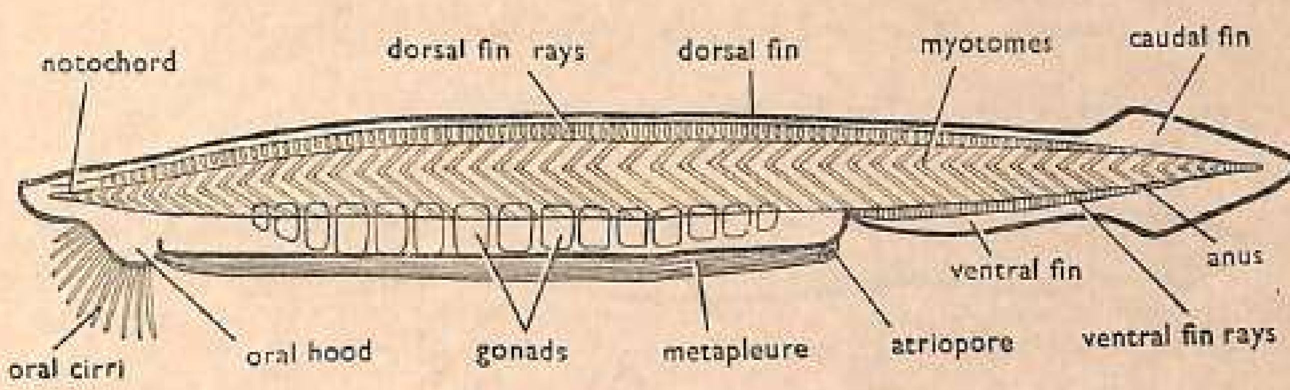


Fig. 3-13. *Amphioxus* in side view.

Comments :

(1) The adult specimen is less than 5 cm. long and has typically fish-like structural set up. The external characters are oriented mainly towards feeding and locomotion. *Amphioxus* is commonly called as **lancelet.**

(2) The **body** is elongated, flattened and non-pigmented and pointed at both ends as the name implies. Anterior end projects forwards as the **rostrum.**

(3) Dorsal, ventral and caudal **fins** are low and continuous. There are 2 lateral fins or **metapleural folds.**

(4) The **mouth** lies ventral and is guarded by **oral hood** containing **oral cirri.**

(5) **Atriopore** is median and ventral. **Anus** on left side.

(6) **Myotomes** are arranged on both sides of the body as metamerical blocks of striated muscle fibres separated by **V–shaped** partitions called as **myosepta** or **myocommata.**

(7) Gonads 26 pairs, metamerically arranged on pharynx.

(8) **Pharynx** is voluminous. It has **gill slits, endostyle, epipharyngeal** groove and **peripharyngeal bands.**

(9) **Notochord** is an axial skeletal extending from anterior to posterior end. **Nerve cord** lies just above the notochord.

Special feature—Although eyes, nose, ears, jaws and appendages are completely absent, but *Amphioxus* is of **special zoological interest,** because it shows three distinctive characters of the phylum Chordata in simple form i.e., presence of **notochord, nerve cord** and **gill slits.** It is considered to resemble some ancient ancestor of the phylum Chordata.

Identification—*By oral hood and shape of the body.*

D. MUSEUM SPECIMENS OF CYCLOSTOMATA

NATURAL HISTORY

The cyclostomes are modern fish-like animals, which seem to be the descendants of old fauna. They are primitive forms without jaws (Agnatha) and lateral appendages. The name Cyclostomata pertains to the circular mouth (*cykos*=circular; *stoma*=mouth). It includes two groups of partial parasites—

(a) **Lampreys** which attach to the body of fishes.

(b) **Hagfishes** which bore into the bodies of fishes and live in the interior until the carcass loses the entire flesh.

13. Petromyzon

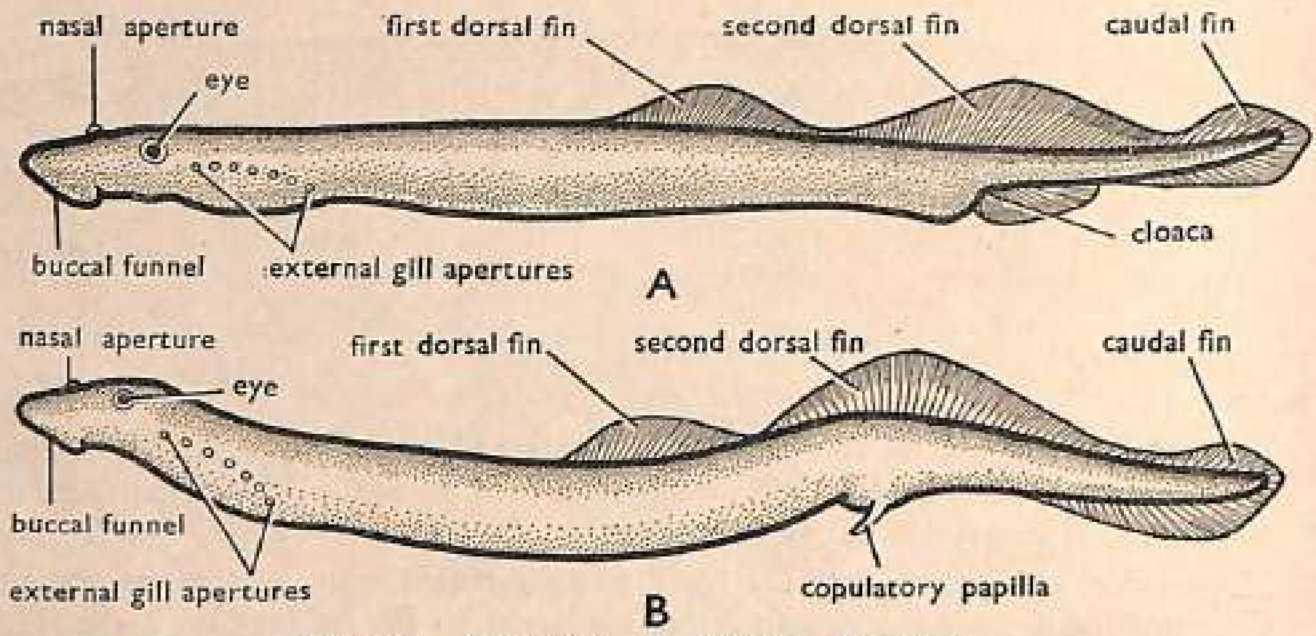


Fig. 3-14. *Petromyzon*. A—Female. B—Male.

Classification :

Phylum............Chordata	→	Dorsal tubulated nerve cord, gill slits and notochord present.
Subphylum........Vertebrata (Craniata)	→	Definitive head, cranium, sense organs, closed circulation, red blood, complex brain, heart of minimum 2 chambers and vertebral column present.
Superclass........Agnatha	→	Jaws and paired appendages absent.
Class...............Cyclostomata	→	Mouth circular, sucking without jaws. Brain simple.
Order.............Petromyzontia	→	One or two dorsal fins present, nasopharyngeal pouch blind and gills open independently to exterior and into respiratory tube internally. Gills 7 pairs. Branchial basket well developed.

Type..............*Petromyzon marinus* (*Lampetra fluviatilis*).

Geographical distribution—*Petromyzon marinus* is found in world-wide sea waters, coastal regions, streams and lakes of **North America, Europe**, West Africa, Australia, Chile, Japan, New Zealand and Tasmania.

Habit and habitat—*Petromyzon* is found both in salt and fresh water. They lead ectoparasitic life on other fishes, attaching to the body of fish by **buccal funnel** and secreting **anticoagulant** for continuous flow of blood. They are also **anadromous** i.e. ascending river for spawning. Carnivorous.

Comments :

(1) *Petromyzon* is commonly called as **lamprey**. The **body** is **eel-like**, measuring about 90 cm.

(2) **Skin** is without scales, slimy, green, brown and with strong metallic lustre.

(3) The body is differentiated into **head**, **trunk** and **tail** with 2 **dorsal** and 1 **caudal fin**. **Head** contains mouth but no jaws.

(4) **Mouth** is surrounded by a large, ventral, **suctorial funnel** with numerous **horny teeth**. The '**tongue**' is toothed and piston-like.

(5) **Nasal sac** dorsal, is unconnected to mouth, and pineal body is present behind nasal opening. Paired **eyes** are large and functional. 2 small median eyes namely pineal and parietal are also present.

(6) **Gill slits are 7 pairs** and **branchial basket** is well developed.

(7) **Sexes** are separate. **Female** with large anal fin. **Male** with **urinogenital papilla.**

(8) **Economic importance :**

(a) Lampreys have very little food value.

(b) They injure and destroy fishes by sucking blood and causing secondary infection.

(c) Larval Lampreys are used as bait for sport fishing and commercial fishing.

Special feature—Lampreys and **Hagfishes** are the lowest **jawless vertebrates** and **their nearest allies** are the ancient **ostracoderms** of **Silurian** and **Devonian periods.** There are no fossil representatives of this group to indicate their course of evolution.

14. *Myxine Glutinosa*

Classification :

Phylum............**Chordata**
Subphylum........**Vertebrata**
Superclass........**Agnatha**
Class...............**Cyclostomata**
} Characters of each same as those of *Petromyzon*.

Order..............**Myxinoidea** → Mouth terminal, with 8 tentacles, funnel absent, gills 10–14 pairs and branchial basket feebly developed.

Type...............*Myxine*.

Geographical distribution—*Myxine* is abundantly distributed along seacoast of the Atlantic and Pacific oceans and found in North European, North Atlantic, American and Japanese sea waters.

Habit and habitat—**Hagfishes** or *Myxine* sometimes descend to a depth of 300 fathoms. They are purely **marine** and are buried in the muddy bottom.

Comments :

(1) *Myxine* is commonly called as **hagfish.**

(2) The **body** is soft without scales, worm-like, measuring about 60 cm. in length and is differentiated into **head, trunk** and **tail.**

(3) Anterior extremity contains **barbels** or **tentacles** on head.

(4) The **mouth** is terminal and surrounded by lips. **Buccal funnels** and **jaws** are absent.

(5) There is a single dorsal fin which extends upto caudal fin.

(6) Eyes vestigial. Due to dark and bottom dwelling habit, photoreceptor organ is reduced.

(7) 10–14 pairs of gills open into a **branchial chamber,** which opens to the exterior by a single branchial opening.

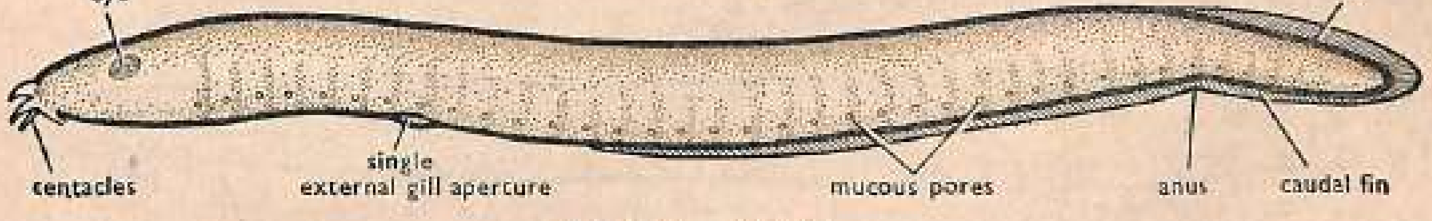


Fig. 3·15. *Myxine*.

(8) Hagfishes secrete enormous mucus through mucous pores.

(9) They are hermaphroditic and protandrous.

(10) **Economic importance :**

(a) Hagfishes damage fish caught in nets.

(b) Sometimes hagfishes enter into the body of other fishes and eat entire soft part, leaving only a bag of skin and the bones.

Special feature—In hagfishes same individual produces sperms and then eggs later on. Development is direct. The hagfishes are injurious to fish industry. They are important from evolution point of view. The evolution of jawed vertebrates from agnathans could be hypothesized as the latter needed only jaws. Although no direct link is available to understand evolution of Gnathostomes, but some armoured agnathan might have served as an ancestor to the jawed vertebrates.

Identification—*By the absence of buccal funnel and presence of barbs in the head.*

15. *Bdellostoma*

Classification :

Phylum............**Chordata**
Subphylum.......**Vertebrata**
Superclass.......**Agnatha**
Class..............**Cyclostomata**
} Characters of each same as those of *Petromyzon*.

Order............**Myxinoidea** → Mouth terminal, with 8 tentacles, funnel absent, gills 10–14 pairs and branchial basket feebly developed.

Type..............*Bdellostoma*.

Geographical distribution : *Bdellostoma* is distributed in the Pacific coasts of North and South America, South Africa and New Zealand.

Habit and habitat : *Bdellostoma* is found buried in mud and sand during day; otherwise it is **nocturnal feeder** and ectoparasitic and highly adapted for sucking.

Comments :

(1) *Bdellostoma* is commonly called as **hagfish.**

(2) Body is elongated, soft, eel-like and without scales.

(3) Teeth are well developed. Jaws are completely absent.

(4) **Eyes** are rudimentary, **skin** sensory. **Eight sensory tentacles** are found around mouth. Single nostril is very close to the mouth.

(5) Single **pineal eye** present at the top of the head.

(6) The **gills** are modified into pouches which are 6–14 in number and they open independently.

(7) Entire body contains double rows of **mucous glands.**

(8) The blood is **isosomatic** with sea water.

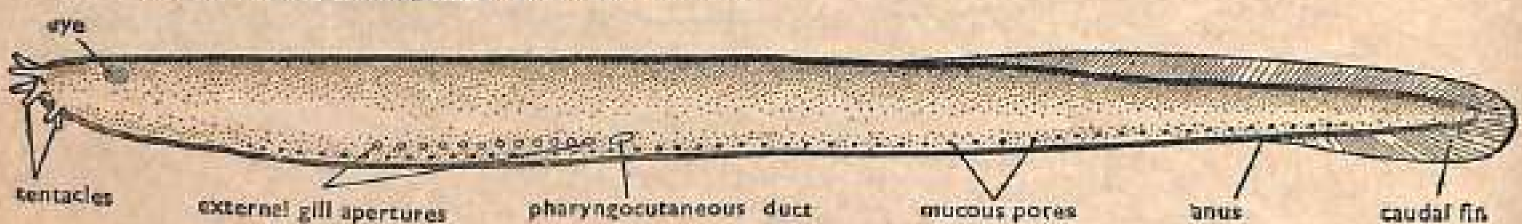


Fig. 3-16. *Bdellostoma.*

(9) The egg is yolky with partial cleavage leading to the formation of an embryo perched on a mass of yolk.

(10) It is **hermaphroditic** and **protandrous.**

Special feature—It has the same phylogenetic importance as that of *Myxine*.

E. MUSEUM SPECIMENS OF FISHES

NATURAL HISTORY

Although several kinds of aquatic animals are called as fishes, such as jelly-fish or starfish, but the word "fish" applies to the first aquatic vertebrates. The **Ichthyology** indicates scientific study of fishes. The common name fish has been derived from a Latin word *Pisces*.

The fishes are characterized by having paired fins and true jaws, presence of scales, gills, cold blood, mesonephros and lateral line. Skeleton may be cartilaginous or bony. Most sharks and rays are marine, but a few live in tropical rivers above salt water. Sharks live in open water, and rays on the bottom. The fishes are predaceous, active swimmers and feed on small fishes. Sharks and rays are used as human food in many countries. Shark liver contains much oil rich in vitamin A. In U. S. A., in 1960, about 30,000 gallons of oil valued at 340,000 was obtained from sharks. Sharks are also a nuisance to fishermen, because they tear nets and steal captured fishes. Large sharks may capsize small boats and injure or kill fishermen. The following outline classification gives a synoptic picture of fishes.

Outline Classification

Phylum..........**Chordata**
Subphylum......**Vertebrata**
Superclass......**Gnathostomata**
Class 1.........**Placodermi**—Extinct fishes.
Order 1.........**Acanthodii**. Ex.—*Climatius*, *Acanthodes*.
Order 2.........**Arthrodira**. Ex.—*Coccosteus*.
Order 3.........**Antiarchii**. Ex.—*Pterichthyodes*.
Order 4.........**Stegoselachii**. Ex.—*Gemuendina*.
Class 2.........**Elasmobranchi or Chondrichthyes**.—Cartilaginous fishes.
Subclass 1......**Selachi**. Ex.—Sharks and rays.
Order 1.........**Squali or Pleurotremata** Ex.—Sharks, *Scoliodon*, *Mustelus*, *Sphyrna*, *Stegostoma*, *Scyllium*, *Phineodon*, *Squatina* and *Chiloscyllium*.
Order 2.........**Batoida or Hypotremata**. Ex.—Rays. *Pristis*, *Rhinobatus*, *Raja*, *Torpedo*, *Trygon (Dasyatis)*, *Urobatis*, *Aetobatus* and *Myliobatis*.
Subclass 2......**Brachyodonti** —Devonian and Recent.
Order 1.........**Eubrachyodonti**—Extinct fishes.
Order 2.........**Holocephali**. Ex —*Chimaera* and *Callorhynchus*.
Class 2.........**Osteichthyes**—Bony fishes.
Subclass 1......**Palaeoptorygii**—Ancient fishes.
Order 1.........**Archistia**. Ex.—*Platysomus*.
Order 2.........**Cladistia**. Ex.—*Polypterus*.
Order 3.........**Chondrostei**.
Family 1.........**Polyodontidae**. Ex.—Paddle fish, *Polyodon*, *Spathula*.
Family 2.........**Acipenceridae**. Ex.—Sturgeon, *Acipenser*.
Subclass 2......**Actinopterygi or Neopterygi or Teleostomi**.
Superorder 1...**Holostei**. Ex.—Bony Ganoids.
Order 1.........**Amiiformes or Amioide or Protospondyli**. Ex.—*Amia*.
Order 2.........**Lepidosteiformes**. Ex.—*Lepidosteus*.
Superorder 2...**Teleostei**. Ex.— Bony fishes proper.
Order 1.........**Isospondyli**. Ex.—Herring, Salmo, Trout, *Tarpon*, *Clupea* and *Sardinops*.
Order 2.........**Haplomi**. Ex.—Pikes and Mud minnows, *Esox lucius*.
Order 3.........**Ostariophys**. Ex.—**Characius**, Electric eels, Suckers, Minnows and Catfishes. *Notopterus*, *Electrophorus*, *Cyprinus*, *Barbus*, *Arius*, *Clarius*, *Wallago*, *Catla*, *Heteropneutus*.

Order 3 a......**Ophiocephaliformes or Hiocephalus.**
Order 4.........**Apodes.** (Anguilliformes). Ex.—Eels. *Muraena, Anguilla, Amphipnous*, etc.
Order 5.........**Synentognathi.** (Beloniformes). Ex.—Flying fishes. *Exocoetus, Belone, Cypselurus, Scomberesox* and *Anabas.*
Order 6.........**Solenienstbye.** (Syngnathiformes). Ex.—Pipe-fishes and Sea-horses. *Hemirhamphus, Xenantodon, Syngnathus, Hippocampus, Fistularia.*
Order 7.........**Percomorphi.** (Perciformes or Acanthopterygi). Ex —Perches. *Huro, Lepomis* and *Scomber.*
Order 8.........**Heterostomata.** (Pleuronectiformes). Ex —Flatfishes, *Pleuronectus, Hippoglossus & Achirus.*
Order 9.........**Plectognathi.** Ex.—*Ostraction, Diodon, Tetradon, Mola mola* and *Fieraster.*
Order 10......**Discocephali.** (Echeiniformes). Ex.—Sucker-fishes. *Echeneis* or *Remora.*
Order 11......**Pediculati.** Ex.—Angler fishes. *Lophius, Antennarius.*
Order 12......**Malaco.**
Subclass 3......**Choanichthyes.**
Superorder 1..**Dipnoi**—Lung fishes.
Order 1.........**Lepidosireniformes.** Ex.—*Lepidosiren, Protopterus.*
Order 2.........**Ceratodiformes.** Ex.—*Neoceratodus, Epiceratodus, Ceratodus.*
Order 3.........**Rhipidistia.** Ex.—*Osteolepis.*
Order 4.........**Coelacanthini.** Ex.—*Eusthenopteron, Macropoma* and *Latimeria chalumnae.*

16. *Scoliodon*

Classification :

Phylum..................**Chordata**	→	Dorsal tubulated nerve cord, notochord and gill slits present.
Subphylum.............**Vertebrata**	→	Internal skeleton of cartilage or bone (both in some); spinal cord forming main axis and composed of overlapping vertebrae. Nervous system dorsal to digestive tract, complex brain. Two pairs of appendages and red blood.
Superclass...............**Gnathostomata**	→	Jaws and paired appendages present.
Class.....................**Elasmobranchi** or **Chondrichthyes**	→	Endoskeleton cartilaginous. Placoid scales in most of specimens. Notochord rudimentary. Spiral valve in intestine, opercula absent in most of fish over gills. Marine and males with claspers.
Subclass..................**Selachi**	→	Sharks and rays. Gills in separate clefts. Cloaca present.
Order.......................**Squali** or **Pleurotremata**	→	(*pleuro*—sides; *trema*=opening). Gill slits lateral, pectoral fins never enlarged.
Family....................**Scyllidae**	→	Asterospondylus. First dorsal fin without spine.
Type.........................*Scoliodon* (Dogfish).		

Geographical distribution—*Scoliodon* has wide distribution. About 4 species are found in Indian sea, all along the Indian coast. Its presence has been reported from Zanzibar, Ceylon to Malay Archipelago, East Indies, Philippine islands, Mexico to Panama, Cuba, West Indies and South America. Lower Carboniferous to Recent.

Habit and habitat (Natural history)—The natural home of *Scoliodon* is the sea, but some live in estuaries and even ascend the rivers. They are **voracious feeders** among schools of fishes. They are **predaceous** and attack their prey with powerful jaws. They are active **swimmers.**

Comments :

(1) *Scoliodon* is commonly called as **dog fish or dog shark.**
(2) It measures about 60 cm. in length.

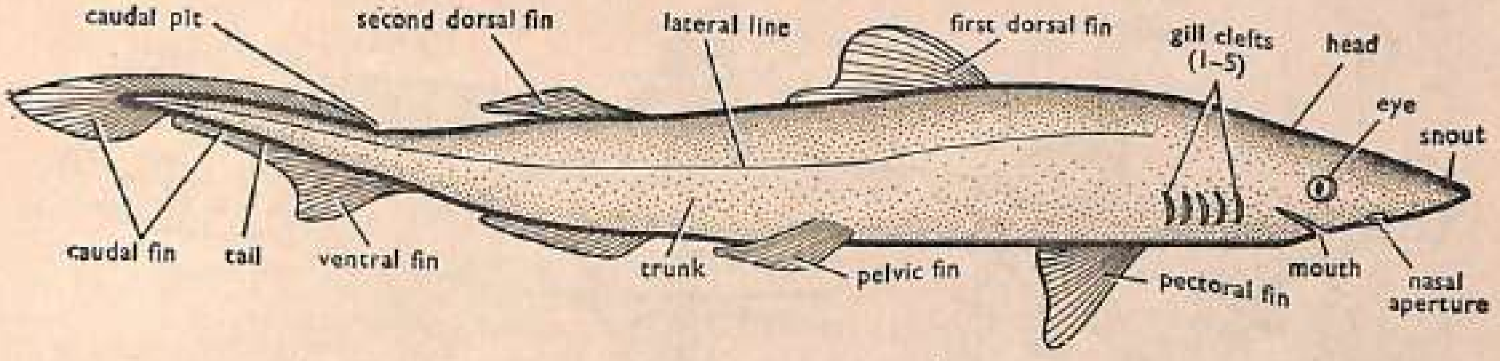


Fig. 3-17. *Scoliodon* in lateral view.

(3) The body is regionated into **head**, **trunk** and **tail** and is spindle-shaped.

(4) The dorsal and lateral sides of the body are **pigmented** dark grey or slaty grey, while the ventral side is white.

(5) The head is dorsoventrally compressed and flattened into snout. It contains ventrally situated slit-like **mouth**, obliquely situated **nostrils** and laterally situated **protuberant eyes**. A little behind eyes there are five pairs of **lateral gill clefts**.

(6) The **trunk** region contains **fins**. There are (i) median **unpaired fins**, and (ii) lateral paired fins. The median unpaired fins are (a) large first dorsal fin, (b) small second **dorsal fin**, and (c) **ventral fin**. The paired fins include a pair of anterior **pectoral fins** and a pair of **pelvic fins.**

(7) Tail contains mainly **musculature**, **vertebral column**. Tail is turned upwards posteriorly. Tail is **heterocercal**.

(8) A pair of pigmented **lateral lines** extends from head to tail.

(9) *Scoliodon* exhibits sexual dimorphism. Males are easily recognized by having a pair of intromittent organs, called as **claspers**.

(10) Cloaca is found between 2 pelvic fins.

Economic importance :

(1) *Scoliodon* has great experimental value because of its availability and size.

(2) It has edible value; it forms a favourite dissection in fishes for undergraduate students.

Special feature (Dogfish and Man)—Sharks are used as human food in many countries. Shark's fins are dried and then boiled to yield a gelatinous substance favoured for soups. The tanned shark skin **shagreen** is used to case fine books, jewel boxes and sword handles, etc. Sharks are a nuisance to fishermen, because they tear nets, steal captured fishes and take bait or fish from hooks.

Identification—*By pointed snout and raised tail and familiar shape.*

17. *Chiloscyllium*

Classification :

Phylum............Chordata → Dorsal tubulated nerve cord, notochord and gill slits present.

Subphylum.......Vertebrata → Internal skeleton of cartilage or bone (both in some); spinal cord forming main axis and composed of overlapping vertebrae. Nervous system dorsal to digestive tract, complex brain. Two pairs of appendages and red blood.

Superclass........Gnathostomata → Jaws and paired appendages present.

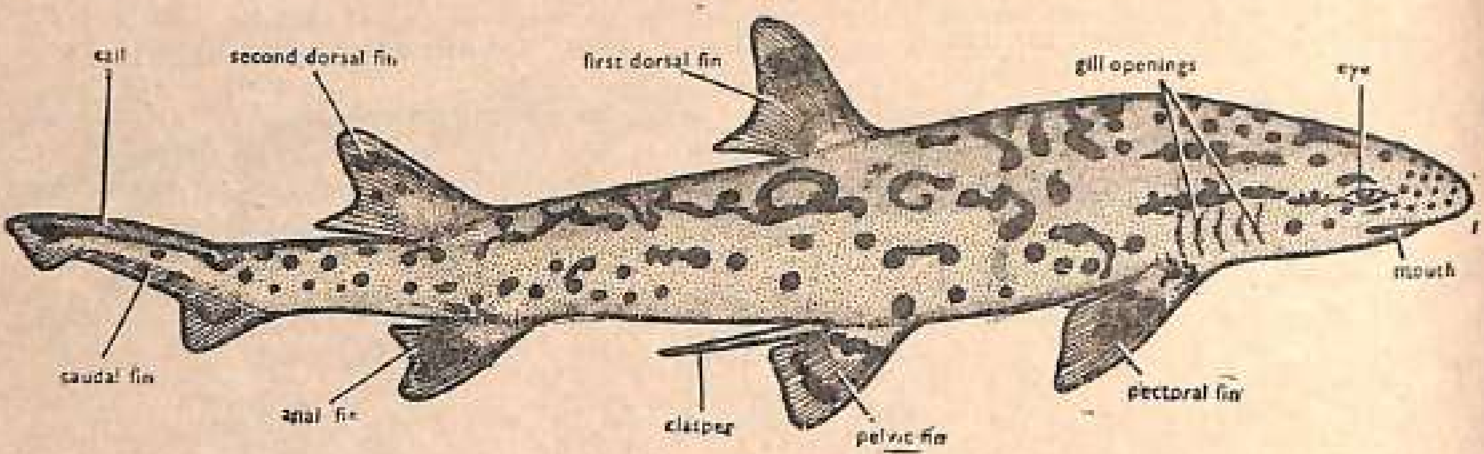


Fig. 3-18. *Chiloscyllium.*

Class..............**Elasmobranchi** or **Chondrichthyes**	→	Endoskeleton cartilaginous, placoid scales in most specimens. Notochord rudimentary. Spiral valve in intestine, opercula absent in most of the fishes over gills. Marine and males with claspers.
Superclass........**Selachi**	→	Sharks and rays. Gills in separate clefts. Cloaca present.
Order.............**Squali** or **Pleurotremata**	→	(*pleuro*=side; *trema*=opening). Gill slits lateral, pectoral fins never enlarged.
Family............**Scyllidae**	→	Asterospondylus. First dorsal fin without spine.
Type..............*Chiloscyllium* (Dogfish).		

Geographical distribution—*Chiloscyllium* is abundantly distributed in temperate and tropical sea water. It ranges from Cape of Good Hope to Indian Ocean, Australia, China and Japan. Lower **Carboniferous** to **Recent**.

Habit and habitat—*Chiloscyllium* is a marine shark, found at a depth of about 400 fathoms.

Comments :

(1) *Chiloscyllium* is commonly called as true **dogfish**.

(2) It is a fish of moderate size. Body is laterally compressed and differentiated into **head, trunk** and **tail**.

(3) **Body surface** is mottled with **grey** and **white bands**.

(4) **Head** is produced into a snout. It contains lateral **eyes** without **nictitating** membrane, ventral mouth and nostrils.

(5) The **median fin** consists of **two dorsal fins** devoid of spines. The first dorsal fin and second dorsal fin are found behind **pelvic** and **anal fins**, respectively.

(6) **Tail** is very slightly turned upwards.

(7) The **spiracles** are present behind the eyes.

(8) The **mouth** contains small **teeth** provided with median **cusps**.

(9) It is **sexually dimorphic**. Males have **claspers** which act as **intromittent organ.**

(10) **Fertilization** internal. **Uterus** contains 3–7 developing embryos.

(11) It is oviparous. The egg case is large, quadrate and provided with tendrils for attachment.

Special feature—This dogfish is also very important to fisheries as its liver contains much oil rich in Vitamin A.

Identification—*By grey and white bands.*

18. Stegostoma

Classification :

Phylum.....................**Chordata**	→	Dorsal tubulated nerve cord, notochord and gill slits present.
Subphylum..............**Vertebrata**	→	Internal skeleton of cartilage or bone (both in some); spinal cord forming main axis and composed of overlapping vertebrae. Nervous system dorsal to digestive tract, complex brain, two pairs of appendages and red blood.
Superclass..............**Gnathostomata**	→	Jaws and paired appendages present.
Class......................**Elasmobranchi or Chondrichthyes**	→	Endoskeleton cartilaginous, placoid scales in most specimens. Notochord rudimentary. Spiral valve in intestine, opercula absent in most of the fishes over gills. Marine and males with claspers.
Subclass..................**Selachi**	→	Sharks and rays. Gills in separate clefts. Cloaca present.
Order......................**Squali or Pleurotremata**	→	(*pleuro*=sides; *trema*=opening). Gill slits lateral, pectoral fins never enlarged.
Family....................**Scyllidae**	→	Asterospondylus. First dorsal fin without spine.
Type.......................*Stegostoma* (Tiger shark).		

Geographical distribution—*Stegostoma* is abundantly found in the Indian Ocean. Lower **Carboniferous** to **Recent**.

Habit and habitat—*Stegostoma* is found in open water. It is active swimmer and predaceous. It feeds on crabs, fishes and turtles, etc.

Comments :

(1) *Stegostoma* is commonly called as **Tiger shark** and **Zebra shark** because of the handsome and brilliant colouration of dark stripes over yellow ground.
(2) The coloured stripes of anterior region are very distinct.
(3) It measures 3–5 meters in total length.
(4) **Snout** reduced, **head** is broad and thick upper lip contains a pair of **small barbels**.
(5) Body is elongated, laterally compressed and regionated into **head, trunk** and **tail**.
(6) Head contains transverse ventral **mouth** under the surface of the head.
(7) **Eyes** are lateral and without nictitating membrane.
(8) **Spiracles** are distinct structures present just behind the eye.
(9) **Gill slits** 5 pairs in lateral position.
(10) **Tail heterocercal.**
(11) **Asterospondylus, dorsal fin** without **spine** and first **dorsal fin** above or behind **pelvic fins, anal fin** present.

Special feature—**Tiger shark is viviparous.** It is also a nuisance to fisheries because it destroys small fishes. **Zebra** shark is famous for its brilliant colouration and ferocious attack.

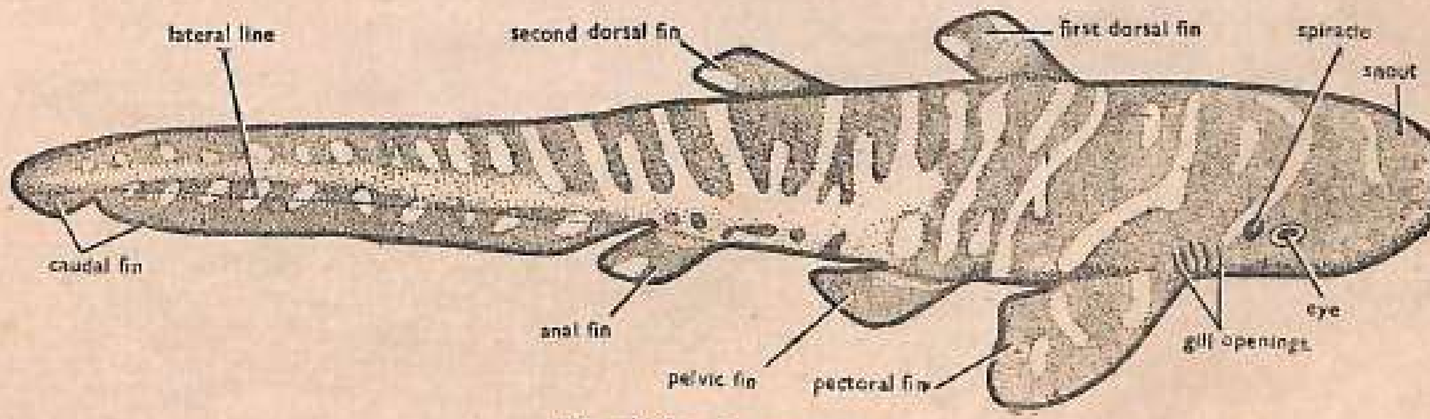


Fig 3-19. *Stegostoma*.

19. Sphyrna

Classification :

Phylum............**Chordata** → Dorsal tubulated nerve cord, notochord and gill slits present.

Subphylum.......**Vertebrata** → Internal skeleton of cartilage or bone (both in some); spinal cord forming main axis and composed of overlapping vertebrae. Nervous system dorsal to digestive tract, complex brain. Two pairs of appendages and red blood.

Superclass........**Gnathostoma** → Jaws and paired appendages present.

Class................**Elasmobranchi or Chondrichthyes** → Endoskeleton cartilaginous, placoid scales in most specimens. Notochord rudimentary. Spiral valve in intestine, opercula absent in most fish over gills. Marine and males with claspers.

Subclass... ....**Selachi** → Sharks and rays. Gills in separate clefts. Cloaca present.

Order..............**Squali or Pleurotremata** → (*pleuro*=sides ; *trema*=opening). Gill slits lateral, pectoral fins never enlarged.

Family.............**Scyllidae** → Asterospondylus. First dorsal fin without spine.

Type..................*Sphyrna* (Hammer-headed shark).

Geographical distribution—*Sphyrna* is found in all tropical and subtropical sea waters and the Pacific Ocean. **Lower Carboniferous** to **Recent**.

Habit and habitat—*Sphyrna* or *Zygaena* or *Reniceps* is common marine fish, adapted for deep sea waters. It is a voracious feeder and active swimmer. It eats small fishes, but because of its attacks on man, it is **dreaded** as **man-eater.**

Comments :

(1) *Sphyrna* is commonly called as **hammer-headed shark,** measuring about 4–5 meters in total length.

(2) The name **hammer-headed shark** is given due to the hammer-shaped **head,** which is produced into two prominent lateral lobes. The lateral lobes are supported by corresponding cartilaginous outgrowths from **post-orbital** or lateral **ethmoidal** regions of skull.

(3) The **eyes** are placed at the distal extremities of the lateral lobes. Eyes contain **nictitating membrane.**

(4) The **body** is elongated and regionated into **head**, **trunk** and **tail.**

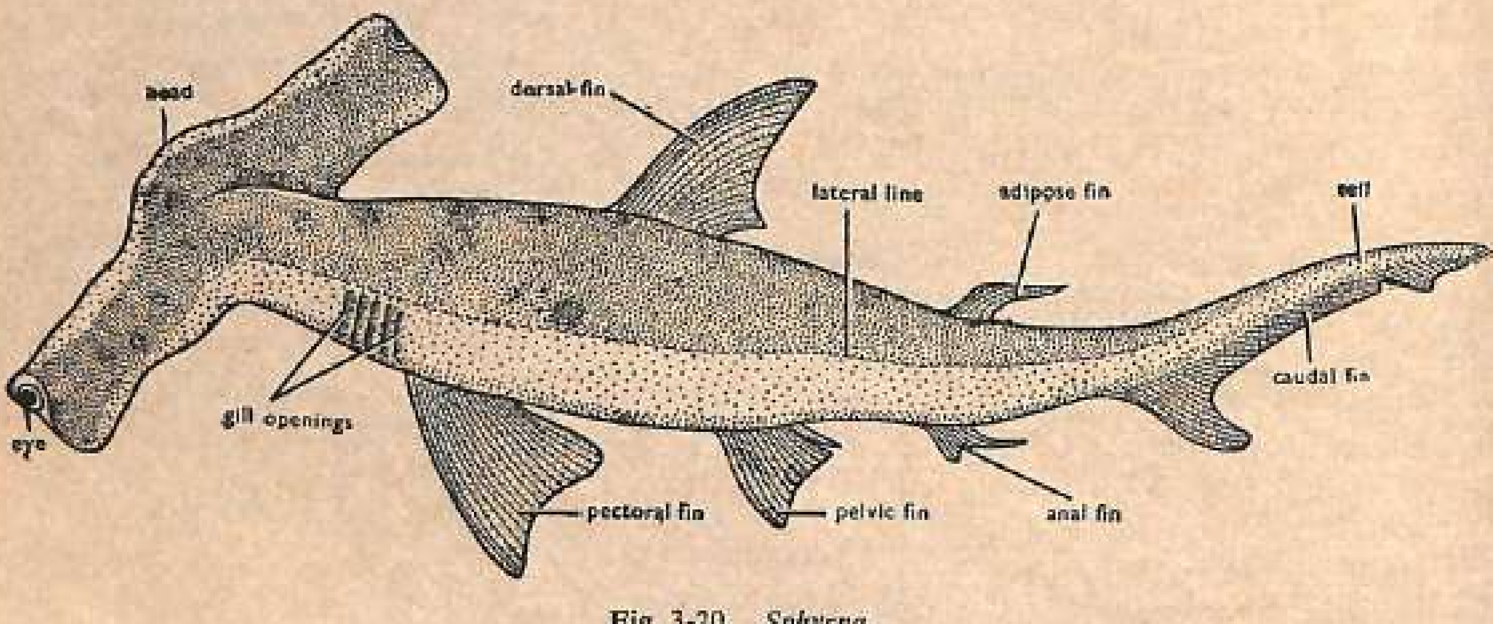


Fig. 3-20. *Sphyrna.*

(5) Two **dorsal fins**; the **first fin** situated in front of **pelvic fin** and second opposite the **anal fin.** Dorsal fins are devoid of **spines.**

(6) **Mouth** is crescentic and ventral in position.

(7) **Spiracles** are absent and **nostrils** lie at the base of lateral lobes.

(8) **Gill slits** 5 pairs and lateral in position.

(9) Vertebrate **asterospondylus.**

(10) The dorsal side is greyish, while ventral side is whitish. Common species are *S. zygaena*, *S. blochii* and *S. fiburo*, etc.

Special feature—Hammer-headed fishes measuring 11–12 feet are very dangerous to mankind. Their attack is very forceful. *Sphyrna* is viviparous and produces about 40 young. It is also captured for its oil.

Identification—*By hammer-headed head.*

20. *Torpedo*

Classification :

Phylum..................**Chordata**	→ Dorsal tubulated nerve cord. Notochord and gill slits present.
Subphylum.............**Vertebrata**	→ Internal skeleton of cartilage or bone, spinal cord forming main axis and composed of overlapping vertebrae. Nervous system dorsal to alimentation, complex brain, red blood and two pairs of appendages.
Superclass.............**Gnathostomata**	→ Jaws and paired appendages present.
Class.....................**Elasmobranchi** or **Chondrichthyes**	→ Endoskeleton cartilaginous, placoid scales in most specimens. Notochord rudimentary, spiral valve in intestines, opercula absent in most of fishes over gills. Marine and males with claspers.
Subclass................**Selachi**	→ Sharks and rays, gills in separate clefts, cloaca present.
Order...................**Batoidea**	→ Skates and rays, gill slits 5, opening ventrally, spiracle present, dorsal fin on tail, if present and vertebrae tectospondylous.
Family..................**Torpidinidae**	→ Trunk in the form of a broad and smooth disk, contains electric organs.
Type.....................*Torpedo* (Electric Ray).	

Geographical distribution—*Torpedo* has been reported from the Mediterranean, Atlantic and Indian oceans, Red Sea, Pacific Ocean, East Indies, Tasmania, China, Japan, South Africa, North and South Americas as well as Australia. **Upper Jurassic** to **Recent.**

Habit and habitat—*Torpedo* is a marine fish, found on flat, sandy or muddy bottom at a depth of 40–50 fathoms. It is **carnivorous.**

Comments :

(1) *Torpedo* or *Astrape* is commonly known as **Electric ray.**

(2) The fish measures 60–90 cm. across the widest part of the disk and the whole body has brown background which is ornamented with beautiful irregularly shaped, magenta-coloured spirals and spots. **Body** is regionated into anterior **semicircular disk** and **posterior tail.**

(3) The disk is supported by endoskeleton. The semicircular region is supported by **branched prenasal rostrum** and laterally by branched **pre-orbital cartilages.** The branches radiate towards periphery.

(4) Disk is bordered by **pectoral fins.**

(5) The **skin** is smooth, non-tuberculate and without **scales.**

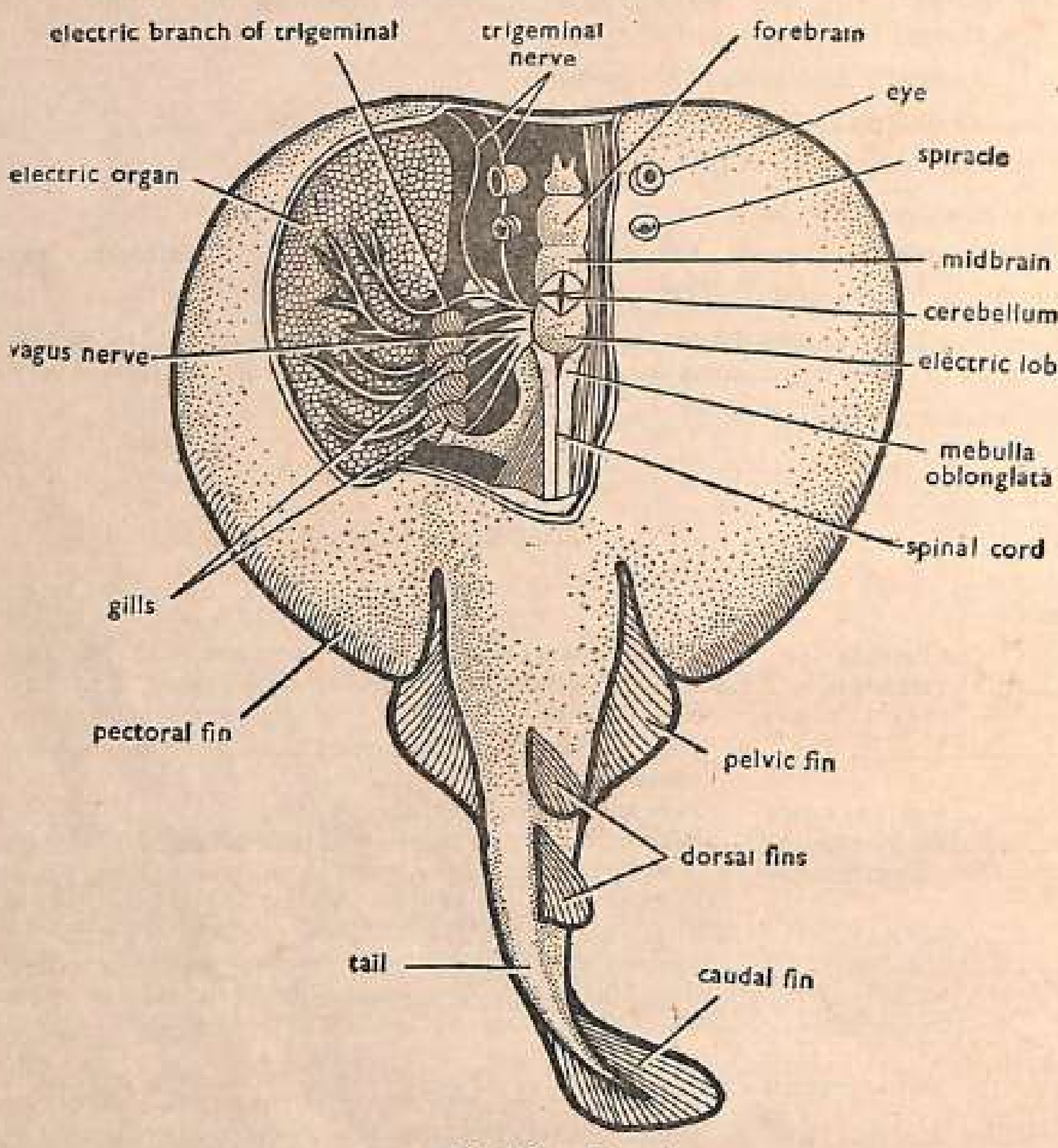


Fig. 3-21. *Torpedo.*
Electric ray partially dissected to show the electric organ and its nerve supply on the left side.

(6) **Eyes and spiracles** are closely placed above electric organs.

(7) **Mouth is** transverse and ventrally situated.

(8) **Tail** is thick and short with **two dorsal fins, a caudal fin** and **two lateral folds** of skin. The **pelvic fins** are just beneath the lower margin of the pectoral fin.

(9) Gills ventral.

(10) Dorsal surface contains a pair of large **electric organs** on either side between head and pectoral fin.

Special features—(1) *Torpedo* contains a pair of large **electric organs between** margins of pectoral fins and head. (2) Each electric organ is composed of hexagonal cells called as **electroplaxes** which are filled with jelly-like fluid and arranged vertically like prisms between upper and lower surfaces. Upper surface corresponds to **anode** and lower surface with the **cathode**. Thus, **electric current** of 50 to 60 volts passes from upper positive to lower negative surface. After fish has discharged electricity, some rest is required for further discharge. There are offensive and defensive organs and fishermen get electric shocks from captured electric rays.

Identification—*By fused pectoral girdle and 2 bulging electric organs.*

21. *Pristis*

Classification :

Phylum......................**Chordata**		Characters same as those of *Torpedo*.
Subphylum..................**Vertebrata**		
Superclass.................**Gnathostomata**		
Class........................**Elasmobranchi**		
Subclass....................**Selachi**		
Order........................**Batoidea**		
Family......................**Pristidae**	→	Snout elongated and saw-like.
Type.........................*Pristis* (Saw-fish)		

Geographical distribution—*Pristis* is found in tropical and subtropical regions. Indian form ascends beyond tidal zones. It is reported from America, Gulf of Mexico, lower Mississippi, the Mediterranean sea and Atlantic waters. Upper **Jurassic** to **Recent.**

Habit and habitat—*Pristis* is warm water marine type. It is **predaceous**, feeding on small fishes and other marine animals. The saw-fishes feed in shallow water on small fishes, which they slash with their saws.

Comments :

(1) *Pristis* is commonly called as **saw-fish.**

(2) The body is elongated, shark like, slightly depressed and measuring about 3–6 meters in total length. It is divided into **head trunk** and **tail.**

(3) Head contains a pair of eyes and a pair of **spiracles** behind the eyes. Water passes through the spiracles and goes out through the gill slits.

(4) Head is anteriorly produced into **a saw-like rostrum.**

(5) Mouth is on the ventral side of the head.

(6) Tail is well developed and ends in a **heterocercal caudal fin.**

(7) The **dorsal fins** are large. First dorsal fin is opposite to **pelvic fin.**

Special features—(1) The important structure is "saw-like" snout, which is formed by the elongation of head and skull. They are flattened in the form of a **rostrum**, which contains a series of strong tooth-like 16–32 pairs of denticles on the lateral margins. (2) The teeth are fixed in sockets, in the calcified rostral cartilage. (3) The **rostrum** acts as organ of offence and defence. (4) *Pristis* is capable of retaining urea in freshwater while ascending in rivers. (5) The fish is also very economically beneficial as its liver oil is rich in **vitamin** value and its skin for making scale boards. **Viviparous.**

Identification—*By saw-like toothed snout.*

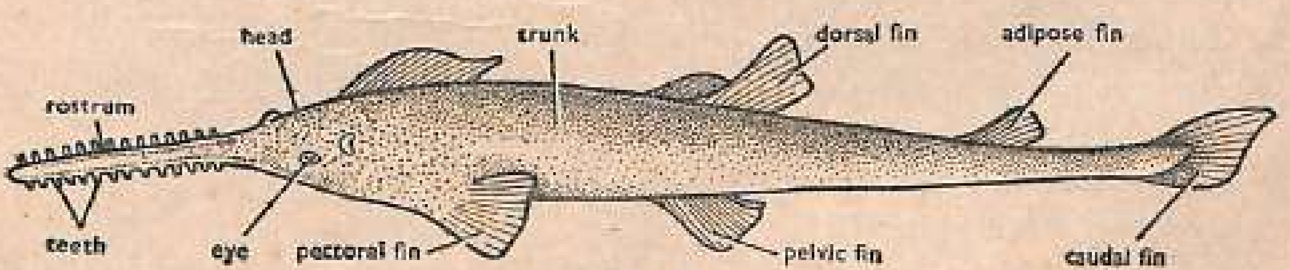


Fig. 3-22. *Pristis.*

22. *Rhinobatus*

Classification :

Phylum......................Chordata	}	Characters same as in the case of *Torpedo*.
Subphylum...................Vertebrata		
Superclass..................Gnathostomata		
Class........................Elasmobranchi		
Subclass.....................Selachi		
Order........................Batoidea		
Family.......................Pristidae	→	Body sub-rhombic, without electric organs.
Type..........................*Rhinobatus* (Guitar fish).		

Geographical distribution—*Rhinobatus* has been reported from west coast of Africa, Indian Ocean, Australia, China, Atlantic and Pacific coasts of America and Galapagos and mostly distributed in tropical and subtropical seas. Upper **Jurassic** to **Recent**.

Habit and habitat—*Rhinobatus* is a bottom dweller.

Comments :

(1) *Rhinobatus* is commonly called as **Guitar fish**, due to its guitar-like shape.

(2) The sub-rhombic head tapers into triangular snout.

(3) The **pectoral fins** are greatly expanded along the head and trunk and consequently body assumes **sub-rhombic shape**.

(4) The entire back contains median row of minute **denticles**.

(5) The **head** and **body** are dorsoventrally compressed.

(6) Head contains a pair of eyes and a pair of **spiracles** closely placed to eyes.

(7) **Gill** slits 5 pairs, ventrally situated.

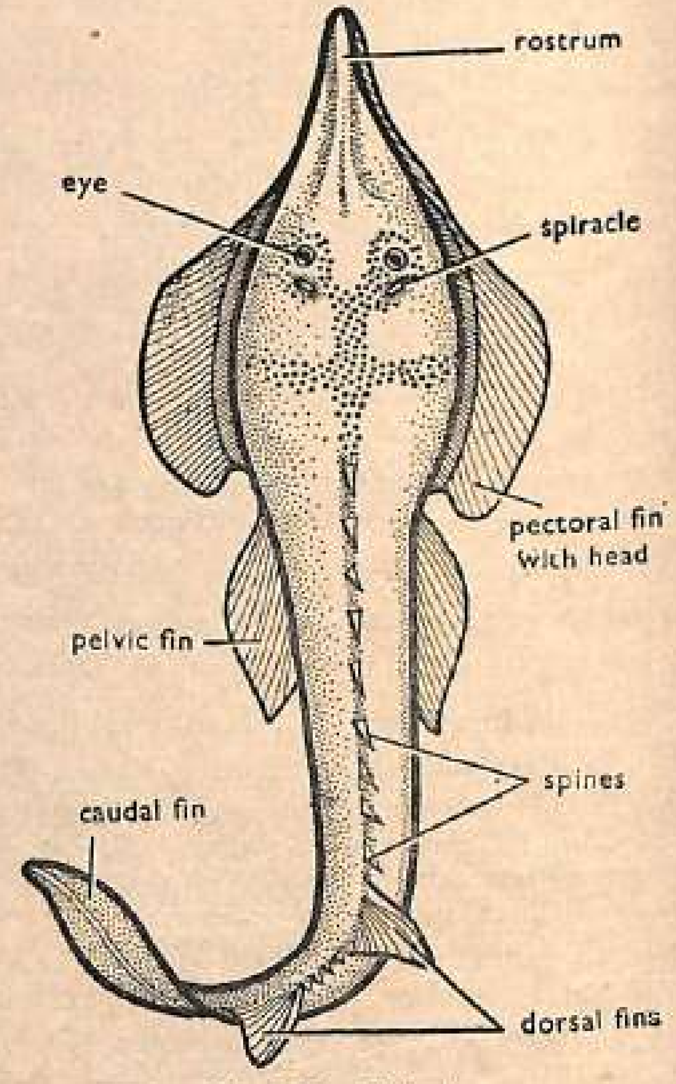


Fig. 3-23. *Rhinobatus*.

(8) **Tail** is elongated and strong with two **dorsal fins**, a **caudal fin** and a longitudinal fold of skin on each side without serrated **caudal spine**.

(9) The pectoral fin does not continue upto snout.

(10) Electric organs are absent.

Special feature—The fish exists from Upper Jurassic. The complete skeleton of *Rhinobatus* has been obtained from lithographic stone of Bavaria, Upper Cretaceous of Mount Lebanon and Upper Eocene of Monte Bolca. It is viviparous and has **edible value.**

Identification—*By guitar shape.*

23. *Raja*

Classification :

Phylum.....................	**Chordata**	Characters same as those of *Torpedo*.
Subphylum..................	**Vertebrata**	
Superclass.................	**Gnathostomata**	
Class......................	**Elasmobranchi**	
Subclass...................	**Selachi**	
Order......................	**Batoidea**	
Family.....................	Rajidae	→ Skates, pectorals extend upto snout.
Type.......................	*Raja*.	

Geographical distribution—*Raja* is found in almost all temperate sea waters. Most of the species belonging to the genus *Raja* are abundantly distributed in northern hemisphere, Arctic and Antarctic regions. Upper **Jurassic** to **Recent**.

Habit and habitat—*Raja* is a marine, sluggish, bottom-dwelling fish. It is **carnivorous**, feeding on small fishes and crustaceans. They catch their prey by dropping over them and covering the prey from all sides from their body and fins.

Comments :

(1) *Raja* is commonly known as **skate**.
(2) Body is dorsoventrally flattened and **rhomboidal**. The colouration of upper surface resembles with sandy or gravelly environment of bottom.
(3) Body is regionated into an anterior rhombic disk and slender tail, measuring about 2–3 meters in width.
(4) Disc is made up by the **head**, trunk and pectoral fins.

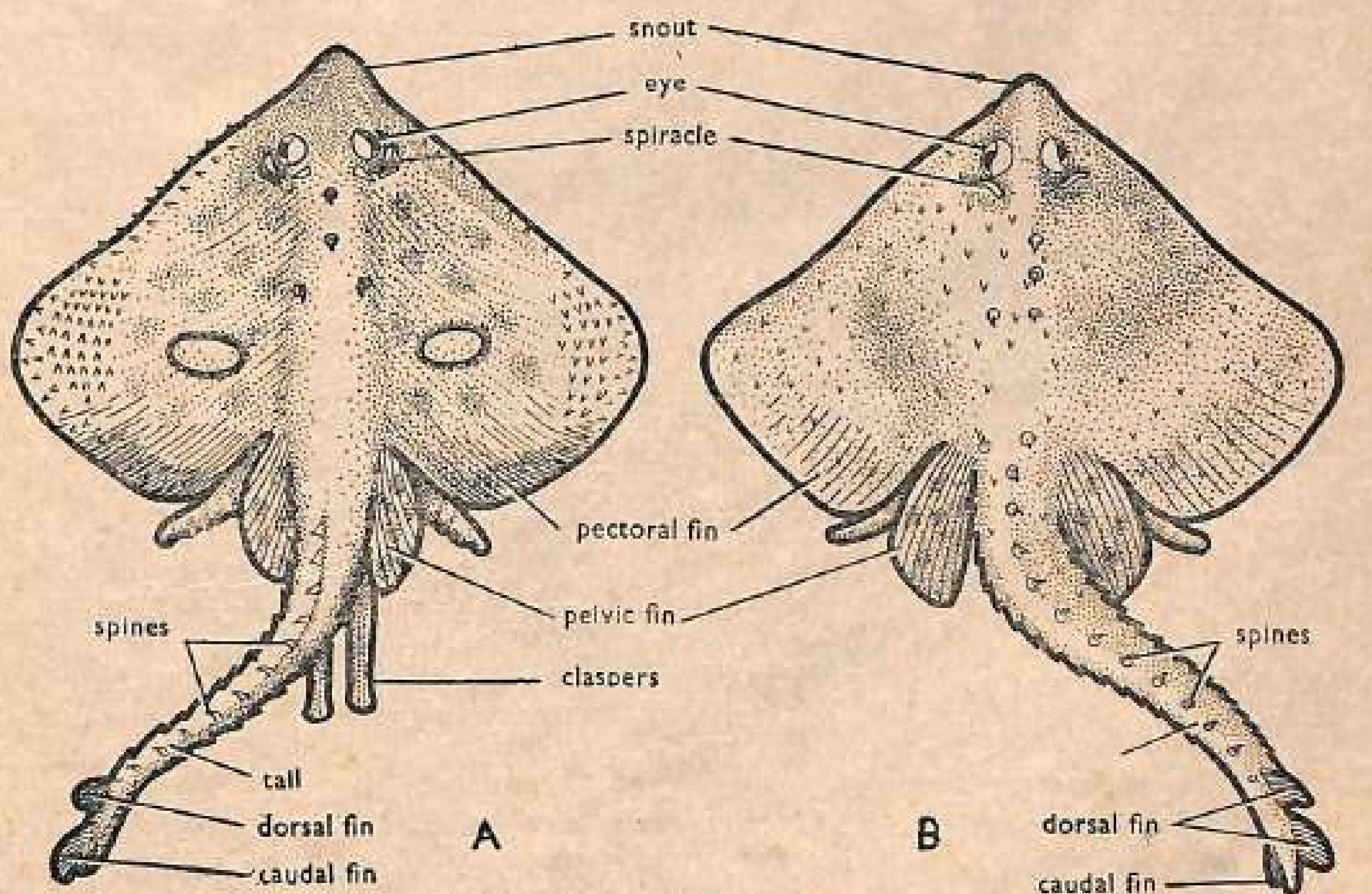


Fig. 3-24. *Raja*. A—Male. B—Female.

(5) **Head** is produced into a short **snout**. It contains a pair of dorsal **eyes**.

(6) **Spiracles** are found just below the eyes.

(7) The ventral **mouth** is provided with the numerous sharp, rasping teeth by which they tear the prey.

(8) The slender **tail** is distinctly demarcated from the rhombic disk.

(9) **Electric organs** are present on tail region. These are modified caudal muscles.

(10) Skin denticular, provided with spines.

(11) Oviparous; egg capsules four horned; sexually **dimorphic**. Male is provided with a pair of **claspers** near the **pelvic fin**. **Caudal fin** is very small.

Special feature—The pectoral **fins** are greatly expanded. They are endoskeletally supported and they extend along the lateral margins of the trunk from the pelvic fins upto the snout. **Tail** contains one median and two additional rows of small spines which inflict severe and irritating wound.

Identification—*By rhomboidal disk with fused pectoral fins.*

24. *Myliobatis*

Classification :

Phylum............**Chordata**	}	Characters same as those of *Torpedo*.
Subphylum.......**Vertebrata**		
Superclass........**Gnathostomata**		
Class...............**Elasmobranchi**		
Subclass...........**Selachi**		
Order...............**Batoidea**		
Family............**Myliobatidae**	→	Disk broader than long and rhombic in shape.
Type................*Myliobatis* (Eagle ray).		

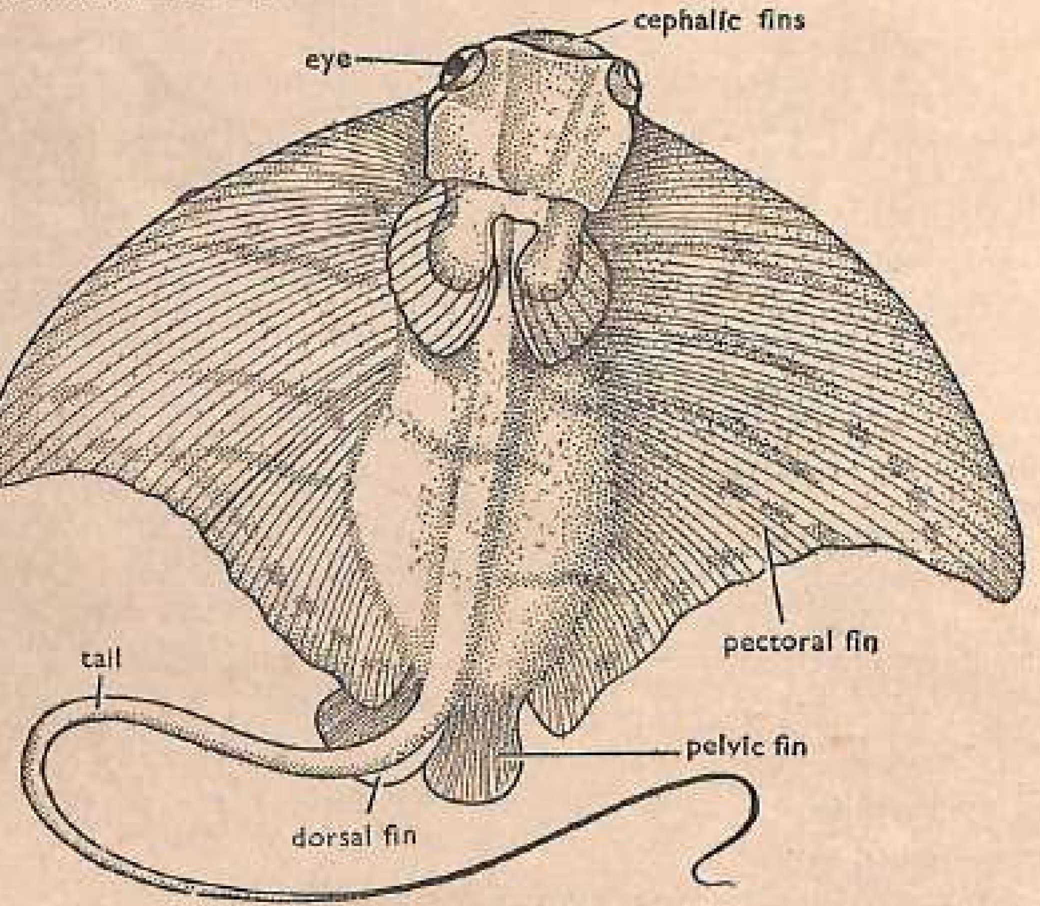


Fig. 3-25. *Myliobatis.*

Geographical distribution—*Myliobatis* is found in tropical and subtropical regions and distributed in the Mediterranean and eastern and southern coasts of England. **Upper Jurassic to Recent.**

Habit and habitat—*Myliobatis* is found in sea water. It is **viviparous** and **carnivorous**. It feeds on small organisms, crustaceans and molluscs.

Comments :

(1) *Myliobatis* is commonly known as **Eagle ray.**

(2) Body consists of a disk and narrow tail. The disk is much broader than long and rhombic in shape. Body is dorsoventrally flattened.

(3) Skin non-tuberculate and devoid of scales.

(4) The **pectoral fins** are enlarged but they do not continue with the snouts; they cease on the sides of the head and reappear in front of snout as distinct folds, called as **cephalic fins.**

(5) The head projects beyond disk. (6) Eyes and spiracles are lateral in position.

(7) Nasofrontal fold is present. (8) **Teeth** are flat, hexagonal and adapted for **crushing.**

(9) Tail is long, cylindrical with a single dorsal fin and one or two serrated spines. Pelvic and caudal fins small.

(10) No sexual dimorphism.

Identification—*By lateral eyes and spiracles.*

25. *Trygon* (Dasyatis)

Classification—Same as those of *Raja.*

Geographical distribution—*Trygon* is abundantly distributed in tropical regions of the Atlantic and Pacific oceans. It has been reported from India, Japan, China, North America, Australia and South America. **Upper Jurassic to Recent.**

Habit and habitat—*Trygon* is found lying quietly on the sea bottom. It occasionally swims to change the place in search of prey or move in self-defence. It is **carnivorous.** It also shows adaptive or **protective colouration** to conceal itself from the enemies.

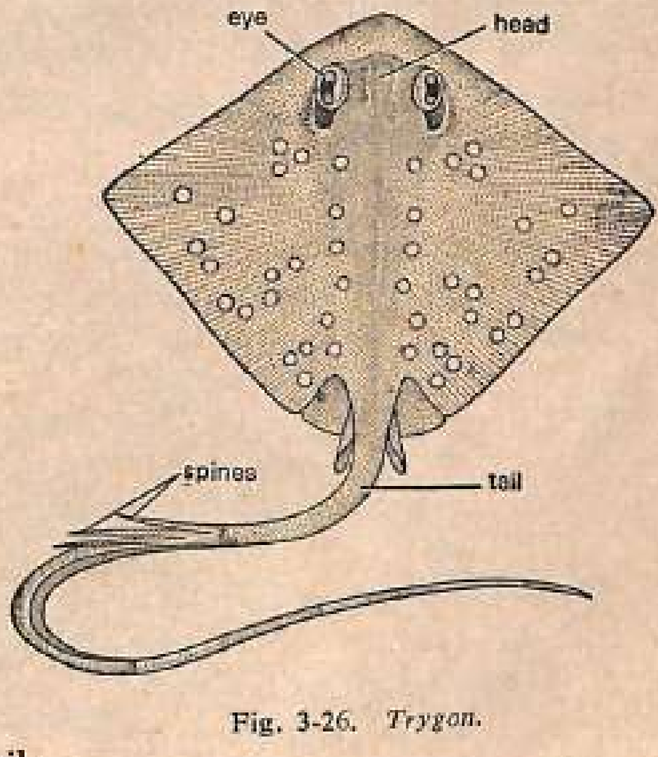


Fig. 3-26. *Trygon.*

Comments :

(1) *Trygon* (Dasyatis) is commonly called as **sting ray** or **whip-tailed ray.**

(2) **Head** and **body** are dorsoventrally compressed. It consists of huge kite-shaped, fleshy body and long whip-like **tail.**

(3) The pectoral **fins** are enlarged and continue upto the end of the snout with the result that body is disk-shaped, **sub-rhombic** and broader than long.

(4) The pectoral fins being confluent with the sides of the head, their pre-axial endoskeletal radiates meet in front of the skull along the lateral margins of prenasal rostral cartilage. **Pelvic fins** small.

(5) Skin is smooth or spiny. (6) Mouth is ventral.

(7) A rectangular **nasofrontal** flap is present in front of the mouth.

(8) Head contains a pair of dorsal eyes. (9) **Spiracles** present behind the eyes.

(10) Gill slits 5 pairs, ventral in position.

Special features—Sexually dimorphic. Male contains claspers near the pelvic fin. The tail is especially elongated, whip like and contains a large mid-dorsal poisonous spine which is a modified dorsal fin. The poisonous spine is about 20-35 cm. long and acts as organ of offence and defence. Caudal fin is small and single lobed. By poisonous sting it inflicts wound on the victim The sting with poison gland produces ugly, slow-healing wound, sometimes complicated by gangrene or tetanus on bathers and fishermen. The flesh of the fish is eaten and the liver gives oil.

Identification—*By whip-like tail.*

26. Chimaera

Classification :

Phylum..................**Chordata**		
Subphylum............**Vertebrata**		
Superclass.............**Gnathostomata**	}	Characters same as those of *Torpedo*
Class........................**Elasmobranchi**		
Subclass...............**Bradyodonti**	...	Dentition of crushing type.
Order......................**Holocephali**	...	Spiracle absent, operculum present, skull autostylic with two dorsal fins and an anal fin.
Family.................**Chimaeridae**	...	Body elongated and shark-like.
Type......................*Chimaera.*		

Geographical distribution—*Chimaera* inhabits the European coasts from Norway to Portugal, Japan and North America. **Upper Devonian to Recent.**

Habit and habitat—*Chimaera* is found at 200–1200 fathoms deep. It eats fish, invertebrates and seaweeds.

Comments :

(1) *Chimaera* is commonly known as **"Rat fish"** or **"King of herrings"**.

(2) **Body** is shark-like with compressed head and blunt snout. The **mouth** is bounded by **lip-like folds.** Mouth and nostril ventral in position.

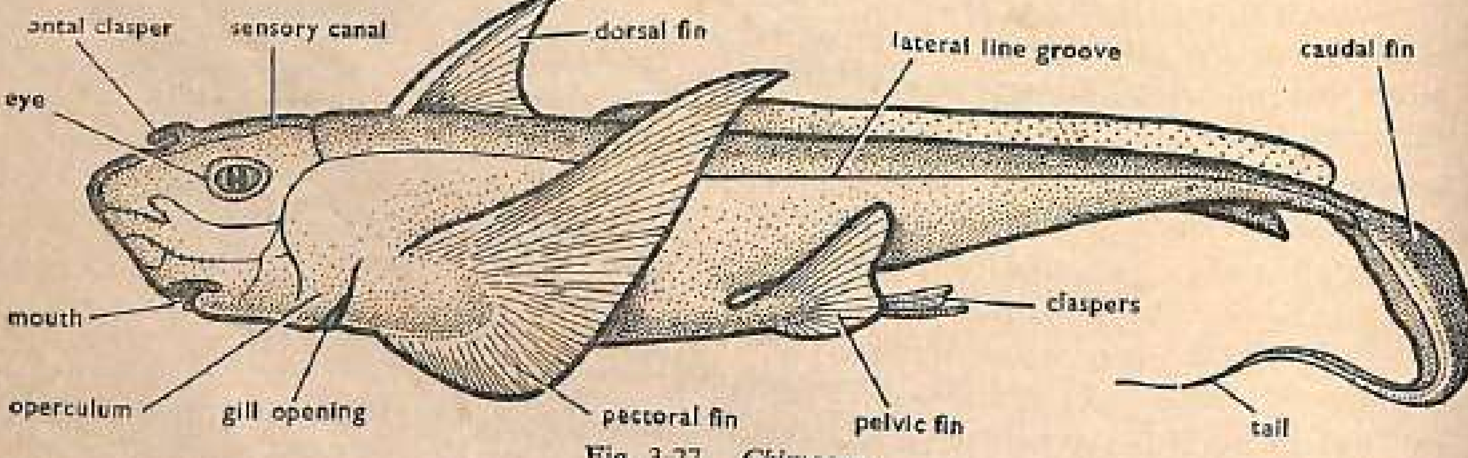


Fig. 3-27. *Chimaera.*

(3) The gill slits communicate with the exterior by a single **branchial** opening. **Operculum** covers the gills.

(4) Spiracles absent.

(5) There are two large **dorsal fins** and a small **ventral fin**. **Caudal fin** is of **diphycercal type**. The **pectoral fins** and **pelvic fins** are enlarged.

(6) The **first dorsal** fin bears an immensely bony anterior **dermal spine** while the **second dorsal** fin is like a folded tail and is produced into the **whip-like filament** and is of **diphycercal** type.

(7) Sexes are separate. **Male** *Chimaera* contains **five claspers**, a **frontal** or **cephalic clasper** on the head, a pair of **anterior claspers** in front of pelvic fins and a pair of **ordinary claspers** near pelvic fins.

(8) **Lateral line** consists of open groove.

(9) **Jaw suspension** is **autostylic**; notochordal sheath contains calcified rings.

(10) The eggs are surrounded by egg shell. **Placoid scales** are found in young **rat fish.**

Natural History—Bony fishes occur from the polar seas to the equator, from the surface to the depths of more than 12,000 feet and in waters more than 12,000 feet deep. They live variously in open water, sandy, rocky or muddy bottoms, in crannies of reefs, in saline bays, estuaries, fresh or alkaline rivers, lakes and cave water, hot and cold springs. Most fishes migrate from salt water to fresh water (**anadromous**) and fresh water to salt water (**catadromous**) for spawning. They are important human protein food. The ancient fishes belong to subclass **Palaeopterygii** and the following table distinguishes some of them :—

1.	**Hyoid gill**, pseudobranch and spiracle	—*Acipenser*
2.	**Hyoid gill**, pseudobranch without spiracle	—*Lepidosteus*
3.	**Hyoid gill**, pseudobranch or spiracle	—*Scaphirhynchus*
4.	Pseudobranch and spiracle without hyoid gill	—*Polyodon*
5.	Spiracle present, pseudobranch and hyoid gill absent	—*Polypterus*
6.	Hyoid gill, pseudobranch and spiracle absent	—*Amia.*

Special feature—*Chimaera* is an interesting fish, intermediate between sharks and bony fishes. Like sharks they have a skeleton of cartilage but unlike them *Chimaera* has small fleshy lipped mouth with tooth plates attached to jaw. Spiracles absent. *Chimaera* further resembles with the bony fishes in **lacking cloaca** and **in having urinogenital aperture** behind anus.

Identification—*By blunt snout* and *additional claspers.*

Bony fishes—The class Osteichthyes comprises of bony fishes, which are notable for their bony skeleton, scales, plates, **air bladder** and advanced brains. Various fishes are found in different types of water—fresh water, brackish water, salt water, warm water and cold water.

27. *Polypterus*

Classification :

Phylum......................**Chordata**	→ Dorsal tubulated nerve cord, notochord and gill slits present.
Subphylum...................**Vertebrata**	→ Internal skeletons of cartilage or bone, spinal cord **forming** main axis and composed of overlapping **vertebrae**, nervous tube dorsal to alimentation, brain complex, two pairs of appendages and red blood.
Superclass..................**Gnathostomata**	→ Jaws and paired appendages present.
Class.......................**Osteichthyes**	→ Bony fishes, skin contains **dermal** scales, paired **lateral** fins present, gills air bladder present and cleavage **meroblastic.**

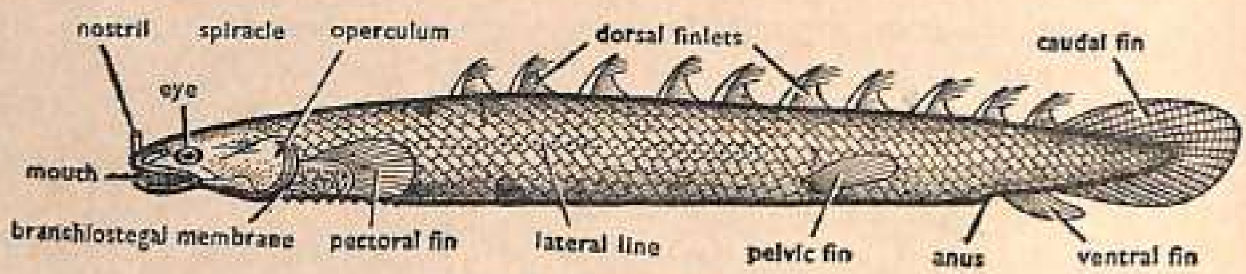


Fig. 3-28. *Polypterus.*

Subclass......................**Palaeopterygii**	→	Ancient fishes, dermal fin rays numerous, clavicles present, nostrils free from mouth cavity.
Order..........................**Cladistia**	→	Body slender, scales thick, rhomboid, enamelled air bladder lung like.
Family........................**Polypteridae**	→	Pectoral fins lobate, while pelvic fins non-lobate.
Type...........................*Polypterus* (Bichir).		

Geographical distribution—*Polypterus* is restricted to tropical Africa, the Nile, Nigeria and Congo. **Palaozoic** and **Recent** (none known species).

Habit and habitat—*Polypterus* is found in sea water. It becomes active during night. It feeds on small teleosts, batrachians and crustaceans.

Comments :

(1) *Polypterus* is elongated, measuring about 1 meter in length.

(2) Head is covered with a horny shield containing tubular **nostrils** and eyes.

(3) **Body** is covered with **ganoid** scales, which are bony, rhomboid and thickly enamelled with **ganoin.**

(4) The **dorsal fin** consists of a series of isolated **finlets** composed of spine-like scales.

(5) **Tail** is symmetrical and **diphycercal.**

(6) Respiratory organs are a pair of **air sacs.**

(7) It cannot live out of water for 3 or 4 hours and it does not leave water.

(8) The **larva** possesses plume-like external gills, attached to the hyoid arch, resembling the gills of Amphibian larva.

Special feature—*Polypterus* shows combination of primitive and advanced characters. **Primitive characters** are non-overlapping scales, spiracle, certain skull bones and its arrangement, spiral valve in intestine and the superficial resemblance of paired fins to broad-based crossopterygian fins. It has also **advanced** features like dorsolateral position of nostrils, pyloric caecum in the gut and similar urinogenital system, which bring them closer to bony fishes. The tail is no longer **heterocercal.** The **air bladder** though connected with pharynx seems to be respiratory organ but remains non-functional as **Polypterus** cannot live outside water.

Identification—*By dorsal finlets.*

28. Polyodon

Classification :

Phylum..............**Chordata**	Characters same as those of *Polypterus.*
Subphylum..........**Vertebrata**	
Superclass...........**Gnathostomata**	
Class...................**Osteichthyes**	
Subclass ....**Palaeopterygii**	

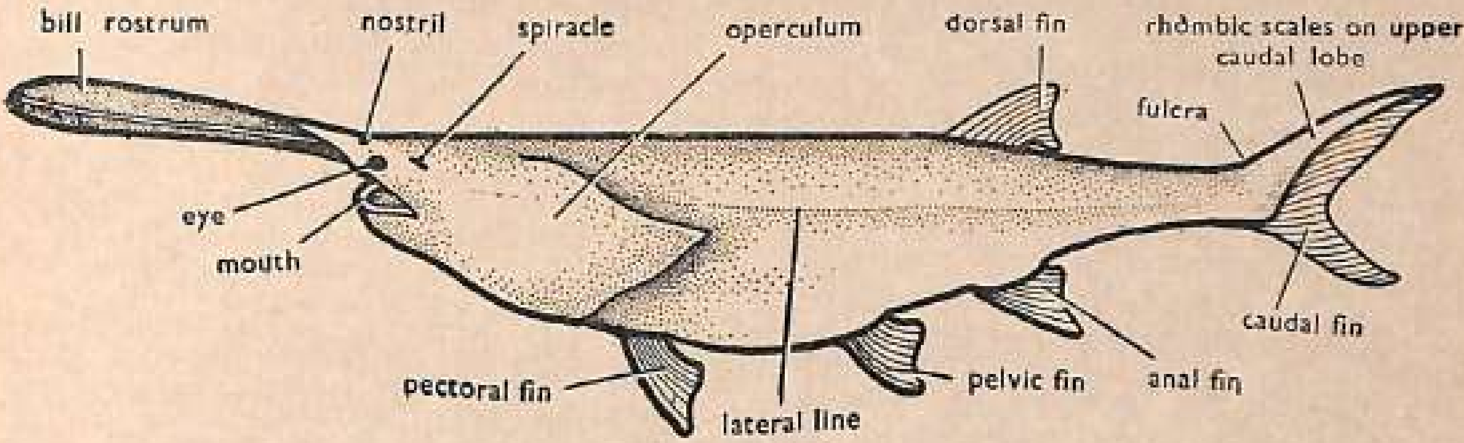


Fig. 3-29. *Polyodon*.

Order..................Chondrostei → Body covered with bony scutes or naked, tail heterocercal, skeleton largely cartilaginous, notochord unsegmented and → vertebrae acentrous.

Family..................Polyodontdae.
Type..................*Polyodon* (Polydora)

Geographical distribution—*Polyodon* is found in the rivers of South and North Americas, Mississippi, Ohio and Missouri. Lower **Jurassic to Recent.**

Habit and habitat—*Polyodon* is a marine fish, sluggish and feeding chiefly on mud with minute organisms. The long bill rakers form efficient filter for taking food. It eats small invertebrates.

Comments :

(1) *Polyodon* is commonly known as **spoon bill** or **paddle-fish.**
(2) **Body** is fusiform, scaleless but vestigeal scales are embedded in skin. It measures 5–6 feet.
(3) **Rostrum** is exceptionally elongated, **spatulate,** conical with rigid axis and flexible margins.
(4) Mouth is wide and ventral. (5) **Barbels** are absent.
(6) **Pectoral fins** do not contain spines.
(7) A poorly-developed **sub-operculum** is present in addition to a small-rayed operculum. **Spiracles** are absent.
(8) **Tail heterocercal.**

Special feature—*Polyodon* also shows combination of primitive and advanced characters.

Identification—*By spatulate rostrum.*

29. Acipenser

Classification :

Phylum............Chordata
Subphylum........Vertebrata
Superclass........Gnathostomata
Class..............Osteichthyes
Subclass..........Palaeopterygii
Order..............Chondrostei
Family.............Acipenseridae
Type...............*Acipenser*.

} Characters same as those of *Polyodon*.

Geographical distribution—*Acipenser* is abundantly distributed in Black Sea, Sea of Azov, Caspian Sea, in rivers of Europe, China and on the Atlantic coasts of North America. Lower **Jurassic** to **Recent**.

Habit and habitat—*Acipenser* is a marine, bottom-dwelling fish. They stir the bottom mud with their snout in search of small invertebrates, worms, molluscs, small fishes and aquatic plants for feeding. They are **migratory** fishes, **anadromous**, ascending rivers for **spawning**.

Comments :

(1) *Acipenser* is commonly known as **Sturgeon**.

(2) It measures 2–4 meters in length.

(3) Body is elongated, cylindrical and bulky and is divided into **head, trunk** and **tail.**

(4) Head contains a pair of **eyes** and functional **spiracles.**

(5) Head is produced into a striking **rostrum**, which is used to stir mud for invertebrates.

(6) The **rostrum** is well developed, having simple or branched **barbels** on ventral surface.

(7) **Jaws** do not contain teeth. There are 4 **barbels** in front of mouth.

(8) The rhombic squamation is confined to the upper lobe of tail, which contains **fulcra. Fins** are without spines, **scales** ganoid. Operculum represented by opercular bone. Dorsal fin single and posteriorly placed.

(9) In the body **scales** are represented by five longitudinal rows of bony scutes with small intervening **ossification.** Each plate is provided with a pointed and partly-conical and backwardly-directed spine.

(10) 2 to 3 **million eggs** are laid by a single fish during the breeding season. The air bladder is smooth, oval and contains ciliated epithelium.

Special feature—*Acipenser* shows **combination** of primitive and secondary modified characters. They **resemble elasmobranchs** in having open **spiracle, heterocercal** tail, **cartilaginous** skeleton mostly, **spiral** valve in the intestine and **conus** arteriosus. Loss of bone shows secondary character and presence of **rhomboid scales** shows its affinity with ganoid fishes. **Black eggs** of European sturgeons are used to prepare a delicacy called as **caviar.** The air bladder of sturgeons is used to prepare **isinglass** meant for cleaning **wines** and **beers.**

Identification—*By scutes and rostrum.*

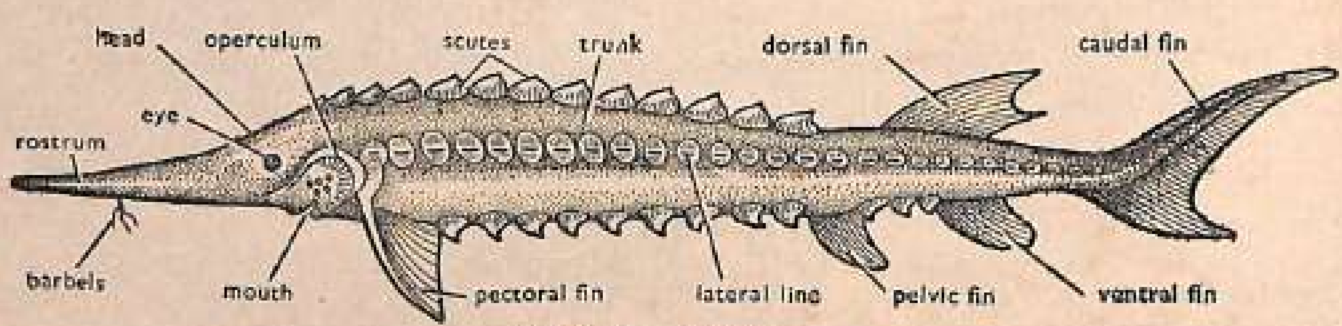


Fig. 3-30. *Acipenser.*

30. *Amia*

Classification :

Phylum............**Chordata**	}	Characters same as those of *Polypterus*.
Subphylum.......**Vertebrata**		
Superclass.......**Gnathostomata**		
Class...............**Osteichthyes**		
Subclass...........**Actinopterygii or Neopterygii**	→	Modern fishes, vertebrae amphicoelous, caudal fin homocercal, scales cycloid or ctenoid and nostrils do not communicate with mouth cavity.
Order..............**Amisformes**	→	Tail heterocercal and overlapping cycloid scales.
Family.............**Amiidae**		
Type................*Amia calva* (Bow-fish).		

Geographical distribution—*Amia calva* is abundantly distributed in rivers and lakes of Central and Southern America. Upper **Jurassic** and Lower **Tertiary**.

Habit and habitat—*Amia* is **a** freshwater fish. It is voracious carnivorous fish, feeding upon other fishes, insects and crustaceans.

Comments :

(1) *Amia* is commonly known as **Bow-fish**.

(2) The shape of body **is fusiform, compressed,** measuring about 60 cm. **It is divided** into head, trunk and tail.

(3) Body is covered by uniformly thin and overlapping and nearly cycloid scales. Ganoin is lost.

(4) **Dorsal fin** is long and anal fin short, all devoid of fulcra.

(5) A single dorsal fin is continuous for the greater part of the trunk and tail.

(6) Head contains ventral **mouth** and dorsal **eyes**. The terminal mouth has a thick **upper lip** and a pair of dorsal **barbels**.

(7) **Teeth** are large, conical and found on premaxillae, maxillae, palatines, dentaries, vomers, pterygoids, splenials and parasphenoid.

(8) Tail is **homocercal**, though **internally** still **heterocercal**.

(9) Sexually dimorphic. Males are smaller than females (45 cm.) and provided with a rounded black spot at the base of caudal fin.

(10) Two peculiar comb-like structures are found on the throat.

(11) The male builds a nest and **guards** the young until they are able to move themselves.

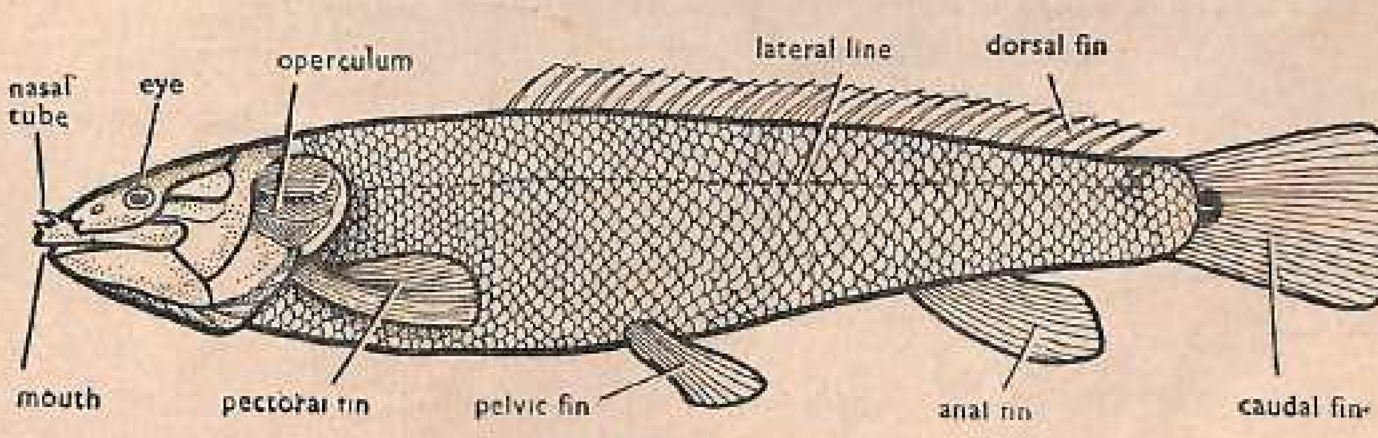


Fig. 3-31. *Amia calva*.

Special features—*Amia calva* is the only one living species. *Amia* shows combination of primitive and advanced characters. The *primitive* characters include (a) dorsal, cellular and bilobed lung (air bladder), (b) spiral valve vestigial, (c) large jugal plate and well-developed branchiostegal rays, and (d) non-pyloric caeca. The *advanced* characters include (i) thin cycloid scales without ganoin, (ii) fulcra absent in fin, and (iii) tail homocercal and vertebra solid and amphicoelous. This fish also shows parental care.

Identification—*By continuous dorsal fin.*

31. *Lepidosteus*

Classification :

Phylum..........**Chordata**
Subphylum.....**Vertebrata**
Superclass.....**Gnathostomata**
Class............**Osteichthyes**
Subclass........**Actinoptrygii**
} Characters same as those of *Amia*.

Order............**Lepidosteiformes** → Vertebrae solid, opisthocoelus and ganoid scales in oblique rows.
Family..........**Lepidosteidae**
Type.............*Lepidosteus*.

Geographical distribution—*Lepidosteus* is widely distributed in the United States. **Upper Cretaceous** to **Recent**.

Habit and habitat—*Lepidosteus* is found in freshwater rivers. It is a voracious feeder on small fishes. Sometimes, it also comes out of the surface to emit bubbles of gases.

Comments :

(1) *Lepidosteus* is commonly known as **gar-pike**.
(2) Body is elongated with short caudal region, measuring about 2–3 meters.
(3) Body is covered with thick rhombic **ganoin-coated** and articulated **scales**.
(4) The **scales** articulate with one another by peg-and-socket joints.
(5) The **dorsal** and **anal** fins are far back near the **tail**. **Caudal fin** is rounded and semi-heterocercal.
(6) The head is produced into snout. Both upper and lower jaws are provided with small conical teeth.
(7) **Eyes** are well developed. **Gills** are covered by **operculum**. **Nostrils** are found at the anterior end of the beak.
(8) **Vertebrae opisthocoelus** and solid. (9) **Pyloric caeca** branched.
(10) Air bladder is used as lung and air is engulfed through the mouth.

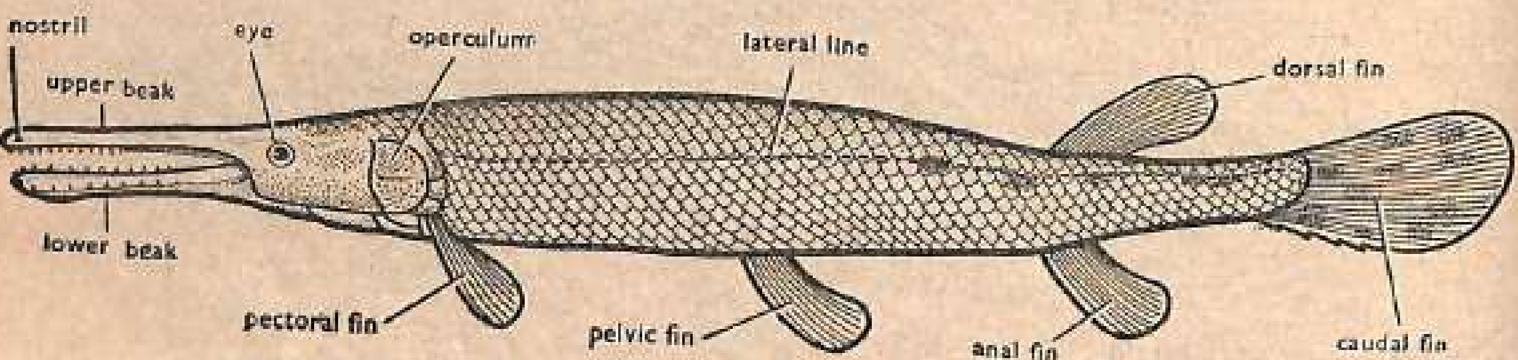


Fig. 3-32. *Lepidosteus*.

Special feature—*Lepidosteus* a shows number of *primitive* features such as cellular air bladder, ganoin-coated scales, presence of fulcra, absence of jugal plate and closed spiracle. It also shows *teleostian* and *advanced* features such as branched pyloric caeca, reduced maxilla, presence of tooth-bearing infra-orbitals and opisthocoelus vertebrae. The scales and the skin of the gars are used in the manufacture of handbags and arts.

Identification—*By the toothed beak or jaws and posterior dorsal fin.*

32. *Salmo*

Classification :

Phylum ....Chordata	}	Characters same as those of *Amia*.
Subphylum........Vertebrata		
Superclass.........Gnathostomata		
Class...............Osteichthyes		
Subclass...........Actinopterygii		
Superorder.......Teleostei	→	Bony fish proper.
Order...............Isospondyli	→	Tail homocercal, fins without spiny rays, air bladder communicates to pharynx with a duct.
Family.............Salmonidae		
Type...............*Salmo salar*.		

Geographical distribution—Freshwater and marine fish. It is found in temperate and Arctic zones of northern hemisphere such as North America—California to Alaska, Europe and Canada. It has been introduced in Kashmir and the Nilgiris. **Jurassic to Recent.**

Habit and habitat—Salmon is found in sea waters. They are famous for their beauty, migratory habits and colour changes. Young migrate to sea and mature in 2 to 8 years, return to fresh water, spawn once and die.

Comments :

(1) *Salmo* is commonly known as **trout.**

(2) Body weighs 13–45 kilograms.

(3) The margins of upper jaw are formed by **pre-maxillaries** and **maxillaries.**

(4) **Supra-occipital** is in contact with frontals and opercular bone is well developed.

(5) A small **adipose dorsal** fin is present on the back.

(6) **Pelvic fin** abdominal. (7) **Tail homocercal.** (8) **Fins** without **spiny rays.**

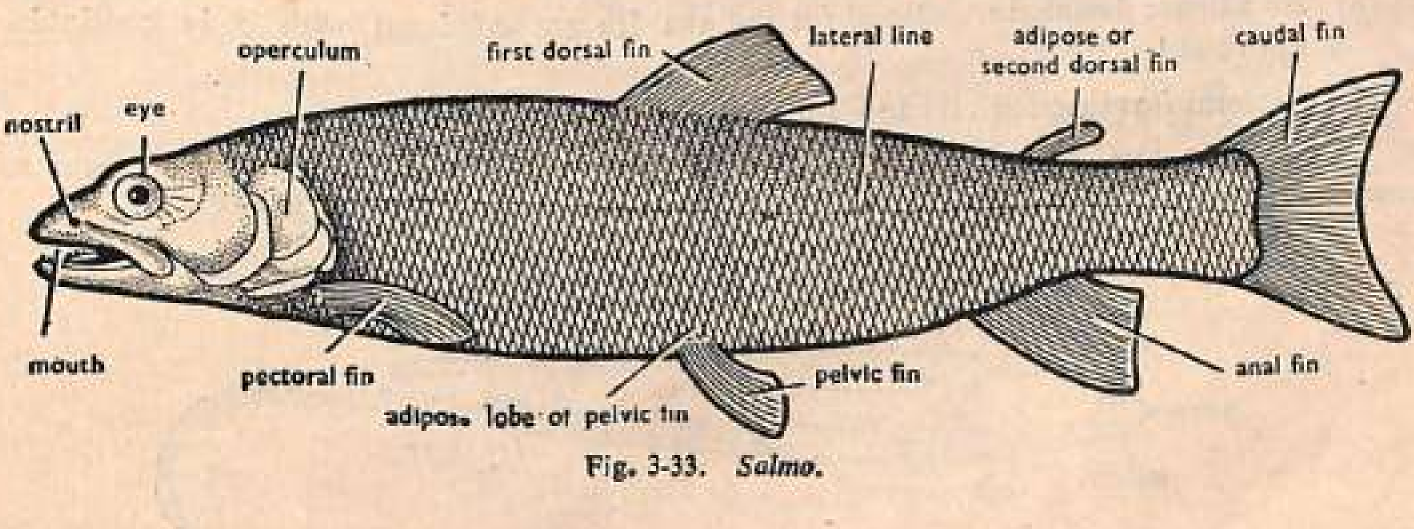


Fig. 3-33. *Salmo.*

(9) **Air bladder** is present, having open duct to pharynx.

(10) Oviduct rudimentary or absent; ova are shed in abdominal cavity before passing to exterior. **Pyloric caeca** numerous.

Special feature—Salmon and trout possess a small adipose fin on the back. They are much poised for food and game. Millions of pounds are taken in nets, used fresh or canned. Various salmon and trout fishes have been transplanted to new localities.

Identification—*By adipose fin.*

33. Esox

Classification :

Phylum............**Chordata**
Subphylum.......**Vertebrata**
Superclass.......**Gnathostomata**
Class.............**Osteichthyes**
Subclass..........**Actinopterygii**
Superorder.......**Teleostei**
} Characters same as those of *Amia*.

Order.............**Haplomi** → Fins with soft rays, pelvic fin abdominal, air bladder communicates with pharynx.

Family............**Esocidae**
Type..............*Esox lucius*.

Geographical distribution—*Esox* is abundantly found in Europe, Northern Asia and U.S.A.—Arkansas and Minnesota eastward and Eurasia. **Jurassic to Recent.**

Habit and habitat—*Esox* is a **marine** fish, **carnivorous** and **predaceous.**

Comments :

(1) *Esox* is commonly called as **pike**.

(2) **Body** is elongated, measuring about 3 meters in length and weighing about 45 kgs.

(3) **Mouth** is large and margin of upper jaw is formed by the pre-maxillaries and maxillaries.

(4) Supra-occipital is in contact with the frontals.

(5) **Opercular bone** is well developed.

(6) **No adipose dorsal** fin. **Dorsal fin** and **anal fin** are confluent with body continuing upto head.

(7) **Pectoral fins** inserted very low and **ventrals** provided with 6-11 rays.

Special feature—**Pyloric caeca** absent. These slender bodied fishes are with large mouths and conspicuous teeth. Some forms grow upto 8 feet and over 100 pounds forming choice game fish.

Identification—*By continuous dorsal and anal fins.*

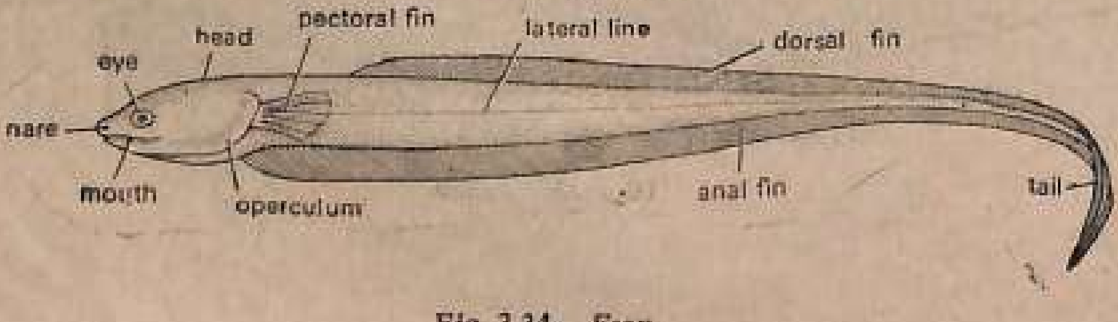


Fig. 3-34. *Esox*.

34. Notopterus

Classification :

Phylum............	**Chordata**	Characters same as those of *Amia*.
Subphylum........	**Vertebrata**	
Superclass........	**Gnathostomata**	
Class...............	**Osteichthyes**	
Subclass...........	**Actinopterygii**	
Superorder........	**Teleostei**	→ Bony fish proper.
Order...............	**Ostariophysi**	→ Anterior vertebrae fused. Weberian ossicles present between air bladder and ear.
Family..............	**Notopteridae**	
Type.................	*Notopterus.*	

Geographical distribution—*Notopterus* is widely distributed in India, Burma, Malaya and West Africa. *N. chitala* is exclusively found in the fresh waters of India. **Eocene** to **Recent.**

Habit and habitat—*Notopterus* commonly inhabits marshy meadows, lakes, fresh water or brackish water. It is a bottom feeder, **carnivorous, predaceous** and feeding on small organisms, insects and crustaceans.

Comments :

(1) *Notopterus* is commonly known as **cat-fish or chital.**

(2) **Body** is very strongly compressed with a short pre-caudal region and measuring about 1½ meters in length.

(3) Colour is silvery dark or greenish on the back or glossy yellow.

(4) **Mouth** is large and descends obliquely. (5) **Eyes** are white.

(6) **Dorsal fin** is short or absent and **ventral fin** is also very much reduced or absent. The **anal fin** is very much elongated and confluent with the **caudal fin.**

(7) **The air bladder** is very large and is divided into several compartments.

(8) **Teeth** are homodont. (9) Gill covers are scaly.

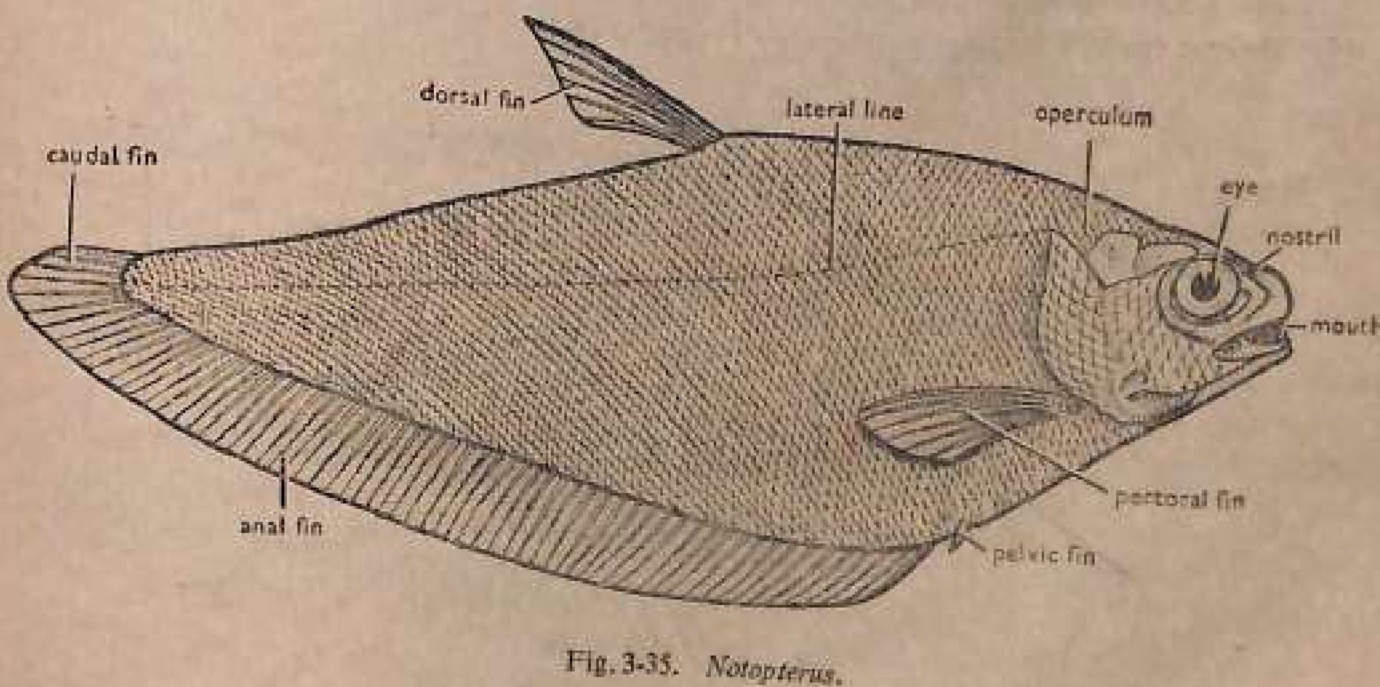


Fig. 3-35. *Notopterus.*

(10) **Musciferous channels** well developed on the head.

Special feature—The flesh of the fish is very rich in nutrition and well flavoured.

Identification—*By confluent anal fin and strongly compressed body.*

35. *Labeo rohita*

Classification :

Phylum............Chordata		Characters same as those of *Amia*.
Subphylum........Vertebrata		
Superclass.......Gnathostomata		
Class..............Osteichthyes		
Subclass...........Actinopterygii	→	Ray-finned fishes.
Superorder........Teleostei	→	Bony fishes proper.
Order...............Ostariophysi (Cypriniformes)	→	Weberian organ present.
Type................*Labeo rohita* (Common Indian Carp).		

Geographical distribution—*Labeo rohita* is widely distributed in tropical and temperate regions specially found in India (Punjab, Assam) and Burma. **Eocene** to **Recent.**

Habit and habitat—*Labeo rohita* is abundantly found in ponds and rivers. Carps are **vegetarian** and bottom feeders.

Comments :

(1) *Labeo rohita* is commonly known as **carp** and **Rohu** in Hindi.

(2) **Body** is compressed, **fusiform** and measuring about 1 meter in length and weighing about 4 kgs.

(3) The colour of the body is bluish or brownish on back and silvery white below.

(4) **Body** is regionated into **head**, **trunk** and **tail.**

(5) **Head** contains **mouth, eyes** and **external nares.** A pair of **filamentous barbels** arises from upper lip. Small **tubercles** cover the snout, which is oblong, depressed, swollen and projecting beyond the jaws.

(6) **Body** is covered by large overlapping **cycloid scales.**

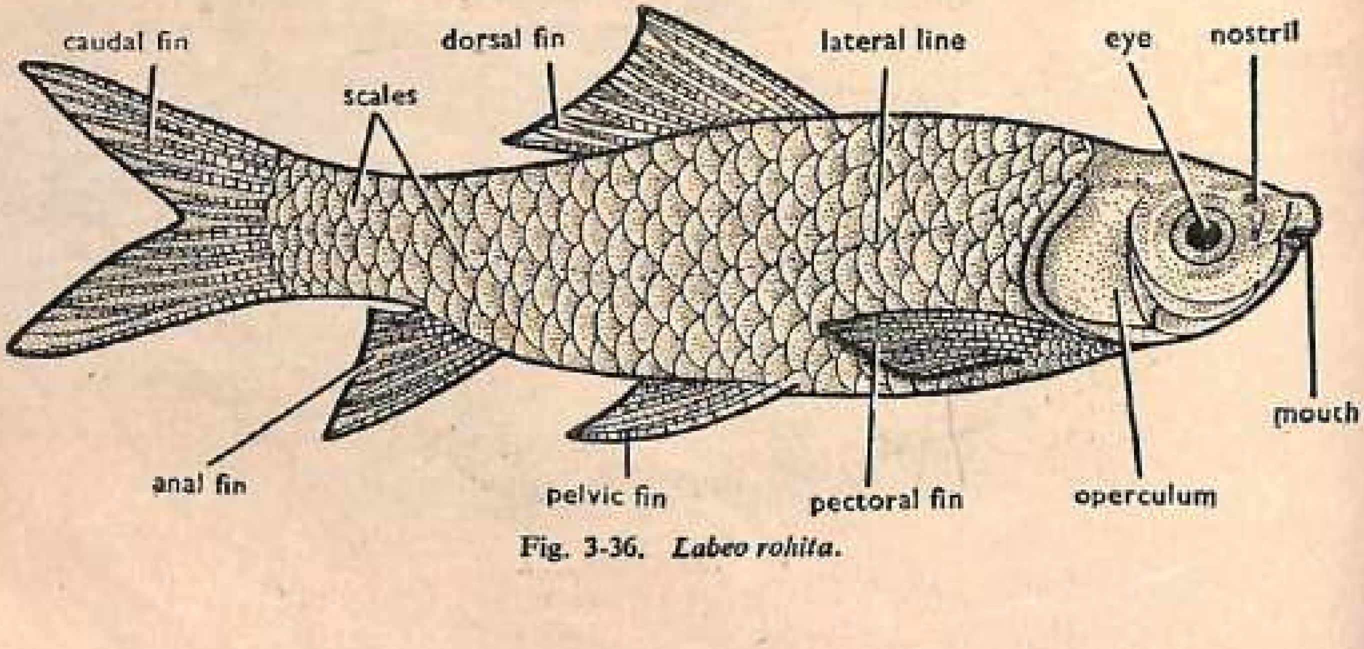


Fig. 3-36. *Labeo rohita.*

(7) **Lateral line** is distinct. The scales overlying the lateral line are perforated by tubes of the lateral line system. These scales are of **taxonomic value.**

(8) *Labeo* contains 7 fins. The **dorsal, ventral and caudal fins** are median fins. The paired **pectoral** and **pelvic** fins are also present.

(9) **Weberian apparatus** present between bladder and inner ear.

Special feature—Mouth does not contain teeth. Teeth are found in pharynx only. **Labeo** has **great** food value, forming common man's food. **The flesh is very delicious. Fin** rays are soft.

Identification—*By overlapping scales*.

36. Clarius

Classification :

Phylum...............**Chordata**
Subphylum..........**Vertebrata**
Superclass...........**Pisces**
} Characters same as those of *Labeo*.
Class.................**Teleostomi**
Order.................**Cypriniformes**
Suborder.............**Siluroidei**
Family................**Calridae**
Type...................*Clarius batrachus*.

Geographical distribution—*Clarius* is distributed in **India, Burma, Sri Lanka** and **Malaya** Archipelago. **Eocene to Recent.**

Habit and habitat—**Clarius batrachus** is found in **fresh** and **brackish** water. It takes a wide variety of food including clams, insect larvae and crustaceans. They act as **scavengers** living in dirty ponds and muddy water.

Comments :

(1) *Clarius* is commonly called as **cat-fish. Body** is divided into **head, trunk** and **tail.**

(2) It is characterized by its **spikeless dorsal fin**, which extends all along the body; **pectorial fin** is inserted very low; **anal fin** is not confluent with caudal.

(3) **Head** is flat with four pairs of non-contractile and sensory **barbels. Head bones** are superficially exposed.

(4) **Body** is covered by **scaleless** and **naked** skin.

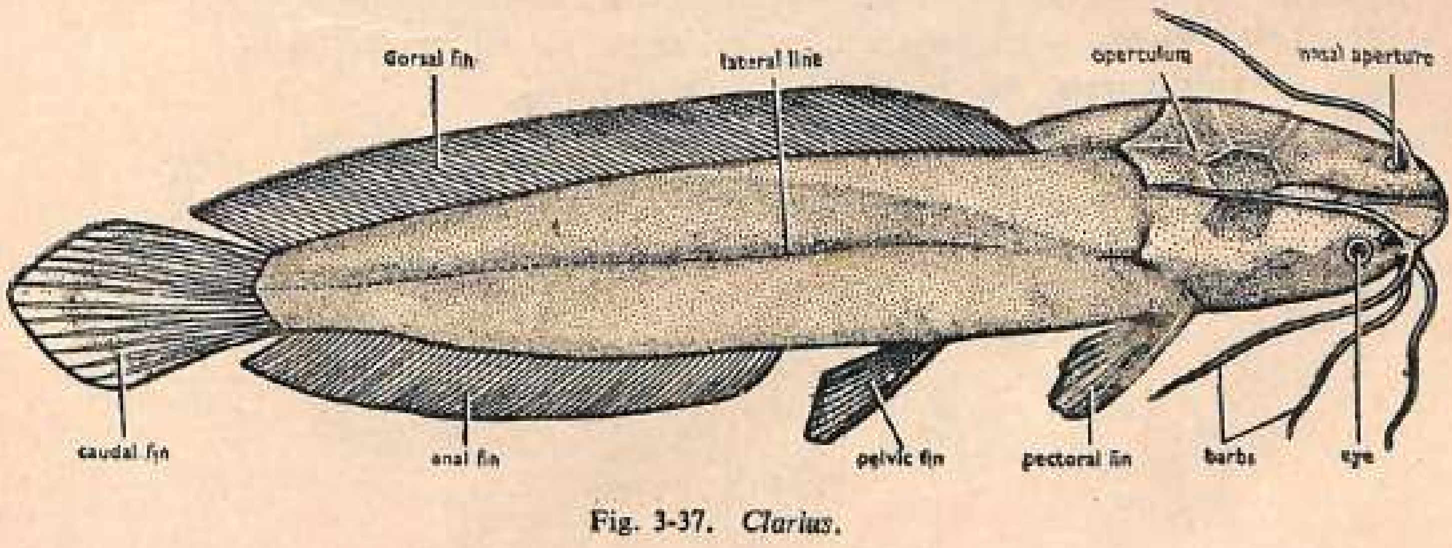


Fig. 3-37. *Clarius.*

(5) **Dendritic accessory** branchial apparatus supplements **gill respiration** and hence fish can live for a very long period outside water.

(6) **Air bladder** is **physostomous.** (7) Eyes reduced and spiracles absent.

(8) Parietals, symplectics and sub-operculum absent.

(9) **Tail** is laterally compressed, **diphycercal** and having rounded **caudal fin.**

(10) **The pectoral fins** cause painful wounds. They are placed very low along ventro-lateral angles of abdomen. **Weberian ossicles** connecting internal ear and air bladder present.

Special feature—Magur supplements gill respiration with accessory organs of respiration. It can remain away out of water for long time. It can also travel a distance of ½ kilometer on its paired fins. On land respiration by accessory respiratory organs. Magurs are much valued for food.

Identification—*By dorsal fin and barbels.*

37. *Wallago attu*

Classification :

Phylum.........**Chordata**
Subphylum...**Vertebrata**
Superclass...**Gnathostomata**
Class..........**Osteichthyes**
Subclass......**Actinopterygi**
Superorder...**Teleostei**
Order..........**Ostariophysi**
Type..........*Wallago attu.*

} Characters same as those of *Clarius.*

Geographical distribution—*Wallago* is distributed throughout India. **Eocene to Recent.**

Habit and habitat—*Wallago* is found in temperate and tropical fresh waters, inhabiting deep-flowing waters of rivers and tanks in hilly and low country regions. It is predacious, feeding on young carps.

Comments :

(1) *Wallago* is also called as **cat-fish.**

(2) The colour of the body varies. Dorsally it is greyish brown, head, is purplish and belly whitish. Body is divided into **head, trunk** and **tail.**

(3) **Head** is very large, trunk small and tail long and tapering.

(4) Clefts of the **mouth** extend behind the orbits.

(5) Head contains **nostrils, 2 maxillary** and 2 **mandibular** sensory **barbels.**

(6) Eyes are found above the level of the mouth and not covered with skin.

(7) Jaws are provided with teeth.

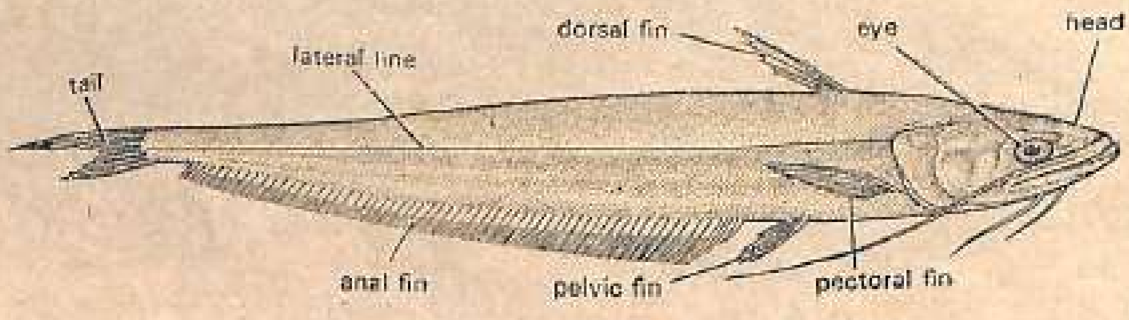


Fig. 3-38. *Wallago.*

(8) **Weberian ossicles** are present. **Gill membranes** free.

(9) **Dorsal fin** is small like pectorals. **Pectoral spine finely serrated. Anal fin** large and confluent with the **caudal fin.**

(10) Scales are absent and body is covered with naked skin.

(11) Teeth **villiform.** Profile of the back oblique.

Identification—*By smooth skin and small dorsal fin.*

38. *Barbus sarana*

Classification :

Phylum...............	**Chordata**	Characters same as those of *Clarius.*
Subphylum..........	**Vertebrata**	
Superclass...........	**Gnathostomata**	
Class....................	**Osteichthyes**	
Subclass..............	**Actinopterygii**	
Superorder..........	**Teleostei**	
Order..................	**Cypriniformes**	
Suborder.............	**Cyprinoidea**	
Family...............	**Cyprininae**	
Type..................	*Barbus sarana.*	

Geographical distribution—*Barbus* is distributed in Burma and India. **Eocene** to **Recent.**

Habit and habitat—*Barbus* is a common freshwater fish of ponds, lakes and rivers.

Comments :

(1) The colour of the fish is silvery white. The operculum is stout with golden colour. Fins are whitish or yellowish.

(2) Body is covered with large scales. Scales are absent on head.

(3) **Barbels** small. (4) Lips simple.

(5) The profile of the back is elevated. (6) **Inter-orbital** space convex.

(7) **Dorsal fin** is opposite to anal fin. **Caudal fin** is bifurcated.

(8) The fish is used as **food.**

Identification—*By scaleless head and simple lips.*

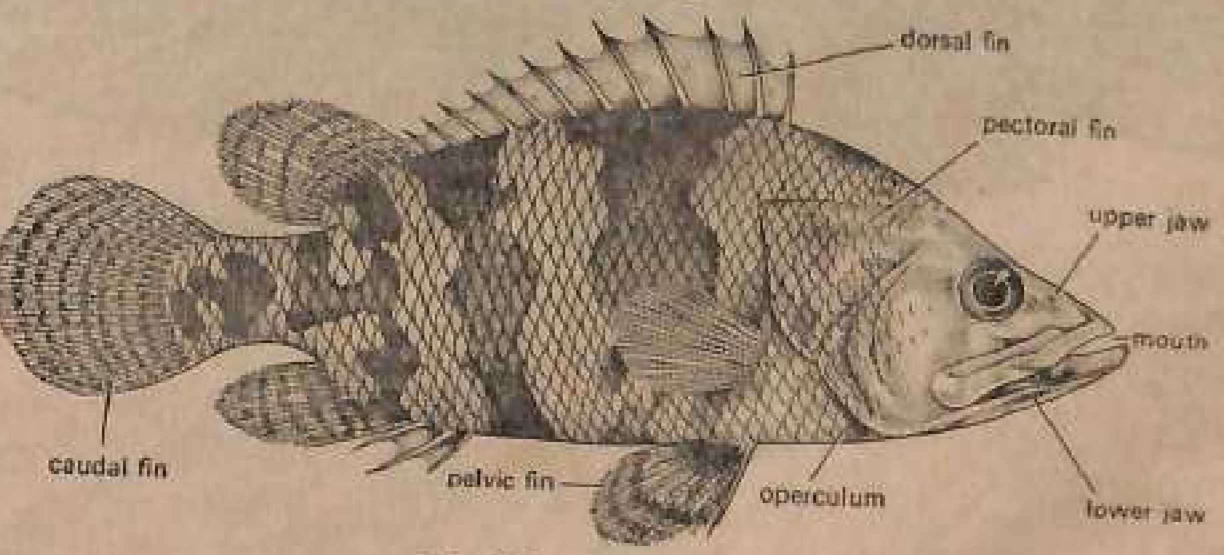


Fig. 3-39. *Barbus.*

39. Ophiocephalus punctatus

Classification :

Phylum............**Chordata**
Subphylum.......**Vertebrata**
Superclass.......**Gnathostomata**
} Characters same as those of *Clarius*.
Class..............**Osteichthy**
Superorder.......**Teleostei**
Order..............**Ophicephaliformes**
Type...............*Ophiocephalus punctatus*.

Geographical distribution—*Ophiocephalus* is distributed in India.

Habit and habitat—*Ophiocephalus* is commonly found in freshwater pond and rarely in flowing waters.

Comments :

(1) The **colour** of the fish varies with water. **Back is greenish** and becoming **yellow** on sides. **Abdomen** is with dark stripes. Some specimens possess scattered **dots** on the head.

(2) Body is elongated and cylindrical and differentiated into **head, trunk** and **tail.**

(3) **Head** is triangular and tapers into a pointed snout. Teeth are present on jaw and palate.

(4) Head is also covered with large scales.

(5) **Pectoral** and **pelvic fins** are small, dorsal fin extends upto tail.

(6) **Caudal fin** is rounded. (7) **Lateral line** is slightly curved.

Special feature—*Ophiocephalus* is eaten as food. Sometimes, raw flesh is used to cure the uclers. It can breathe atmospheric air due to the presence of a supra-branchial cavity. The fish acts as host for camallanid nematodes.

Identification—*By anal and dorsal fin.*

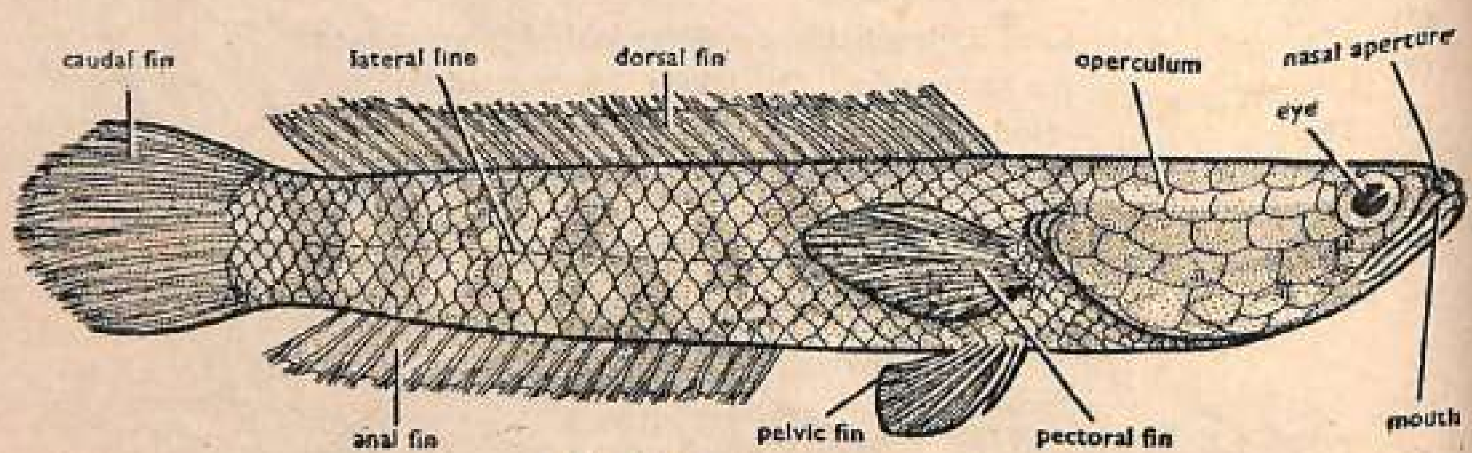


Fig. 3-40. *Ophiocephalus.*

40. *Anguilla*

Classification :

Phylum..............	**Chordata**	Characters same as those of *Labeo*.
Subphylum.........	**Vertebrata**	
Superclass.........	**Gnathostomata**	
Class................	**Osteichthyes**	
Subclass............	**Actinopterygii**	
Superorder..........	**Teleostei**	
Order.................	**Apodes** or **Anguillfiormes**	→ Body long and slender, air bladder with duct, gill openings small, scales minute or absent, dorsal, caudal and anal fins continuous.
Type..................	*Anguilla.*	

Geographical distribution—*Anguilla vulgaris* is widely distributed in Europe, North Africa, temperate Asia, North America, Mexico, West Indies, Australia and New Zealand. **Cretaceous** to **Recent.**

Habit and habitat—*Anguilla* is a freshwater fish. It is **voracious feeder**, **catadromous** fish and it can live for several hours out of water.

Comments :

(1) *Anguilla* is commonly known as **eel**, measuring 4 feet in length.

(2) **Body** of the fish is slender and elongated. Brownish pigments on dorsal surface and ventral surface yellowish.

(3) On each side **operculum** covers the gill slits.

(4) The **dorsal fin**, **anal fin** and **caudal fin** are joined together forming a **continuous fin. Pelvic fins** are absent. Fins are supported by fin rays.

(5) Body is covered by minute scales, which are embedded in the skin, arranged obliquely at right angles to one another forming a curious pattern.

(6) The **maxillaries** and **platopterygoid** present, **gill cleft** separate and **vertebrae** are greatly enlarged.

(7) Spines absent. (8) Gill openings small. (9) Air bladder has duct.

(10) Oviducts absent.

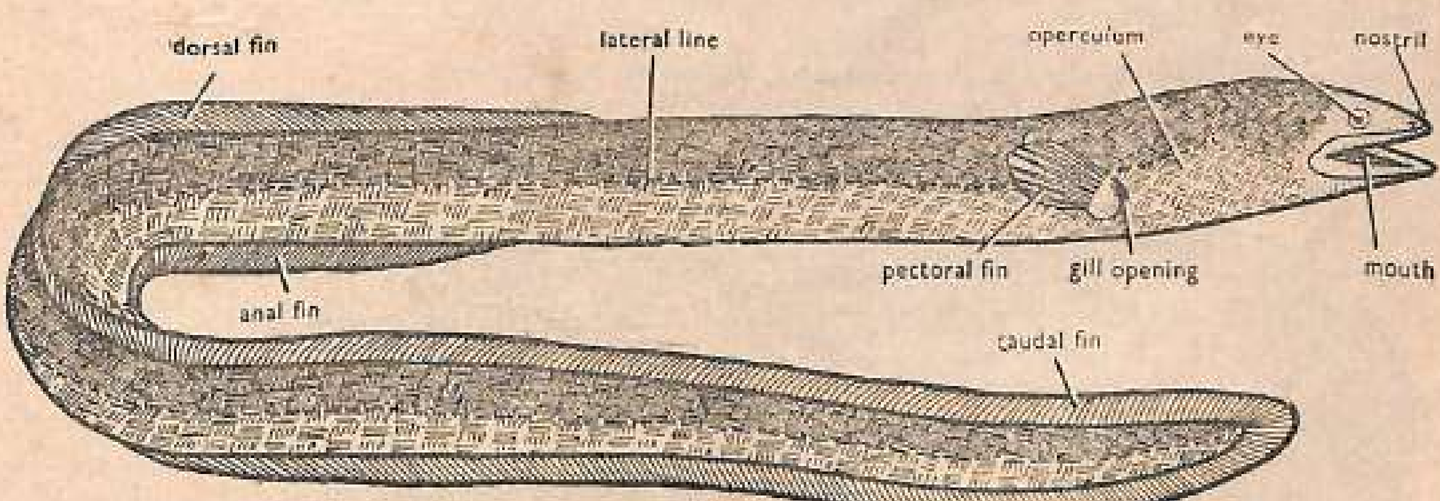


Fig. 3-41. *Anguilla*.

Special feature—*Anguilla* looks like snake. The life cycle is peculiar. The fish (eel) grows to sexual maturity in freshwater streams, the adult male and female migrate to sea in autumn, spawn in deep water and die. The delicate transparent larvae, leptocephali, swim near the surface of the sea, feeding and growing and return to rivers a year later.

Identification—*By continuous caudal, anal and dorsal fins.*

41. *Amphipnous cuchia*

Classification :

Phylum.................Chordata		
Subphylum............Vertebrata		
Superclass...........Gnathostomata		
Class....................Osteichthyes	Characters same as those of *Labeo*.	
Subclass..............Actinopterygii		
Superorder............Teleostei		
Order....................Symbranchiformes		
Type.....................*Amphipnous.*		

Geographical distribution—*Amphipnous* is distributed in India and Burma.

Habit and habitat—*Amphipnous* is found in fresh and brackish water. It is an amphibious fish. It frequently rises to the surface for the purpose of respiration and is often found lying like a snake in the grassy sides of ponds.

Comments :

(1) Body of the fish is long, about 1 meter in length.

(2) The colour of the body is brownish with numerous black spots.

(3) Body snake like. (4) Chief respiratory organs are two air bladders.

(5) The body is slimy without scales.

(6) Paired and median fins are absent. Caudal fin is reduced. A membranous flap without rays is present around tail.

(7) Nostril valve opens above the orbit.

Special feature—*Amphipnous* has a respiratory air sac on each side of the neck behind the head and continuous with the gill cavity.

Identification—*By scaleless snake-like body.*

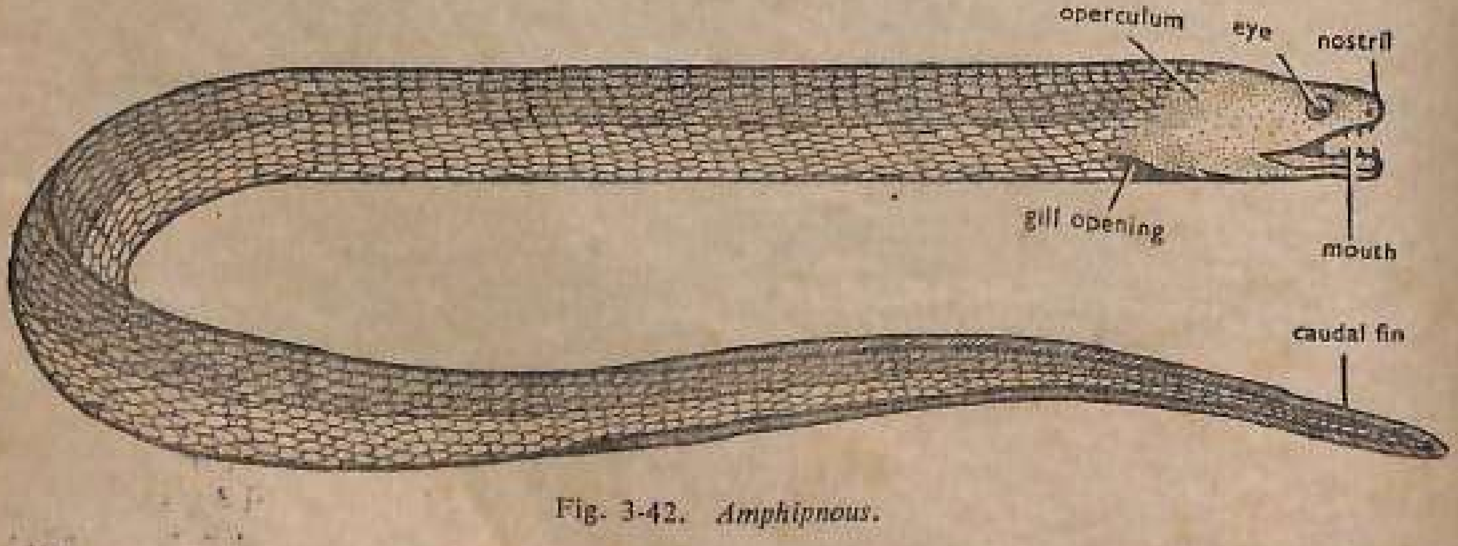


Fig. 3-42. *Amphipnous.*

42. *Pterois*

Classification :

Phylum..............**Chordata**
Subphylum........**Vertebrata**
Superclass.........**Gnathostomata**
Class.................**Osteichthyes**
Subclass............**Actinopterygii**
Superorder........**Teleostei**
Order...............**Perciformes**
Type..................*Pterois* (The Scorpion Fish).

(Subphylum to Superorder:) Characters same as those of *Labeo*.

Geographical distribution—*Pterois* is widely distributed all over the world. **Cretaceous** to **Recent.**

Habit and habitat—*Pterois* is a marine fish. It is sluggish fish. **The** fish adopts its surrounding colour. **Carnivorous.**

Comments :

(1) *Pterois* is commonly called as **scorpion fish.**

(2) Head **incompletely cuirassed,** provided with membranous processes and spines and rest of the body elongated and compressed.

(3) Body is covered with scales. Body is divided into **head, trunk** and **tail.**

(4) **Head is spiny,** containing large **eyes,** nostrils and mouth.

(5) **Pectoral fin** is large and **dorsal fin** is provided with strong spiny rays and soft rays containing **poison glands.**

(6) The spines infect serious and painful wounds.

(7) **Air bladder physoclistic.** (8) Gills pseudobranchiate.

(9) Spiracles absent. (10) **Skeleton** is ossified.

Special feature—*Pterois* is dangerous, if attacked, using its sharp, grooved and dorsal spines like hypodermic needles. It injects stinging and paralyzing venom.

Identification—*By spiny dorsal fin.*

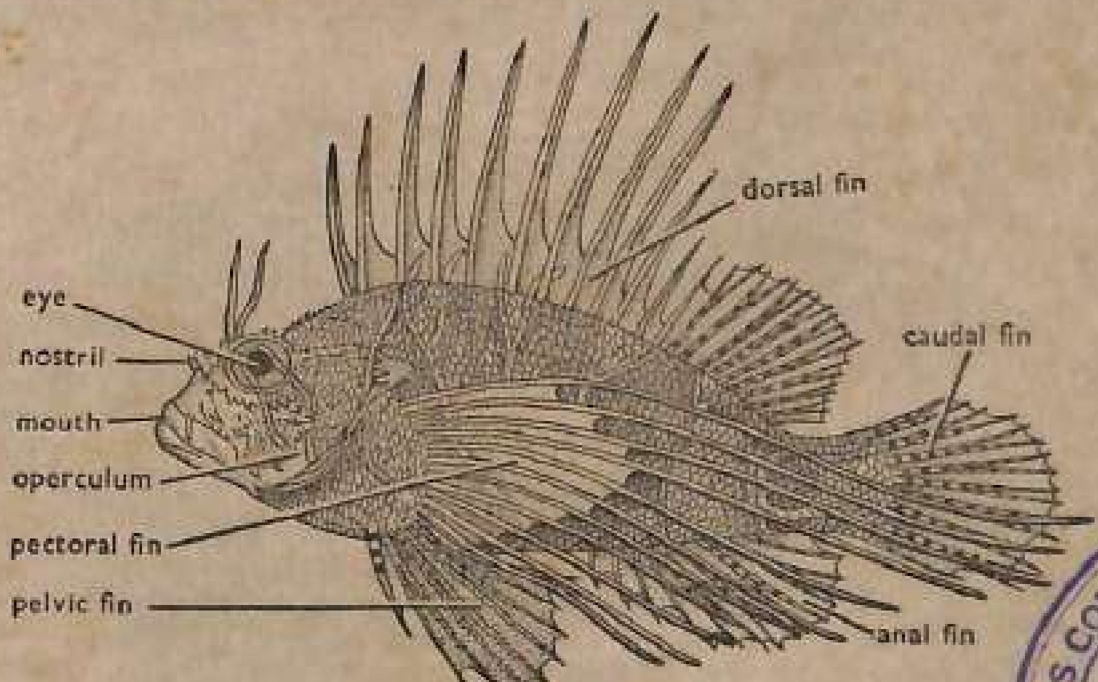


Fig. 3-43. *Pterois.*

43. Anabas

Classification :

Phylum	**Chordata**	
Subphylum	**Vertebrata**	Characters same as those of *Labeo*.
Superclass	**Gnathostomata**	
Class	**Osteichthyes**	
Subclass	**Actinopterygii**	
Superorder	**Teleostei**	
Order	**Percomouphi**	→ Perches. Dorsal and anal fins with spiny and soft fin rays. Pectoral arch attached to skull by forked post-temporal.
Family	**Anabantidae**	
Type	*Anabas* **(The Climbing Perch).**	

Geographical distribution—*Anabas* is distributed in Burma, Sri Lanka and Malaya Archipelago. **Upper Cretaceous to Recent.**

Habit and habitat—*Anabas* is a common South Indian freshwater fish. It can live out of water for a long period.

Comments :

(1) *Anabas* is commonly known as **climbing perch.**

(2) Body of specimen is measuring about 30 cm. and is olive green in colour.

(3) Body is covered by cycloid scales and is perch like. Body is divided into **head, trunk** and **tail.**

(4) **Head** is **conical** containing large **eyes,** nostrils and mouth with small conical teeth.

(5) In front of the eyes there is a pre-orbital bone containing **spines.**

(6) Small spines also occur along the edge of the **operculum.**

(7) The dorsal and anal fins are elongated, anteriorly situated almost below pectorals.

(8) **Dorsal** and **anal fins** are divided into anterior and posterior parts, supported by **stiff** and soft rays respectively.

(9) The accessory respiratory **super-branchial** organ is well developed, having thin and folded bony laminae covered with mucous membrane. Air bladder **physoclistous.**

(10) Tail is perfectly **symmetrical.**

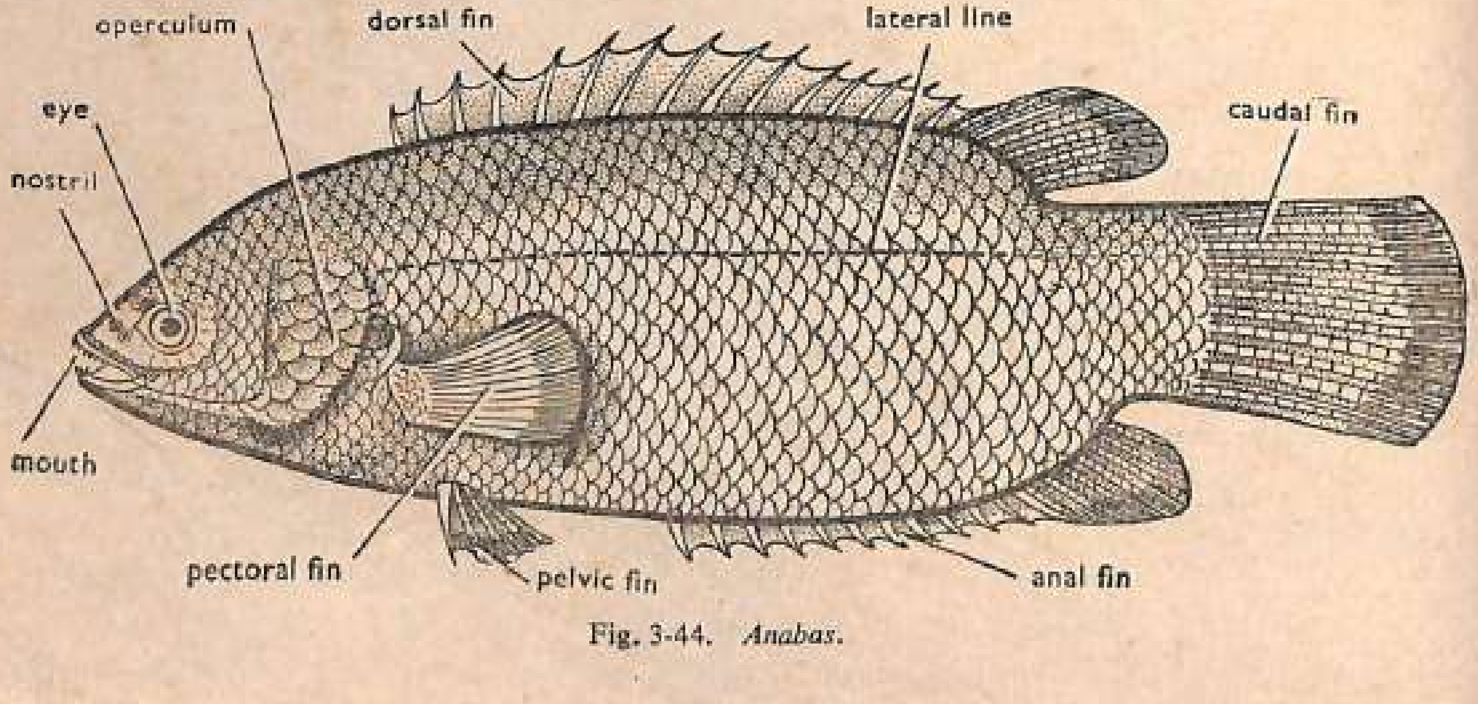


Fig. 3-44. *Anabas.*

Special feature—*Anabas* is able to walk on land by spines in search of earthworms. The crows and kites attack them and take their bodies over trees, and the fish is called as **climbing perch,** as the fish might have climbed trees. But the fish cannot climb the tree. *Anabas* is so much dependent on atmospheric oxygen that it is asphyxiated if kept in water with no access to air. Fish can live out of water for a long period.

Identification—*By dorsal and anal fins and their rays.*

44. *Exocoetus*

Classification :

Phylum............**Chordata**	}	Characters same as those of *Labeo*.
Subphylum.......**Vertebrata**		
Superclass........**Gnathostomata**		
Class..............**Osteichthyes**		
Subclass..........**Actinopterygii**		
Order..............**Synentognathi**	→	Flying fish, dorsal fin above anal pectorals high on body.
Type...............*Exocoetus.*		

Geographical distribution—*Exocoetus* is distributed in tropical and warmer Atlantic and Indian oceans.

Habit and habitat—*Exocoetus* is found in sea, often skittering near the boats. It is pelagic and feeding on prawns and young fishes and their eggs.

Comments :

(1) *Exocoetus* is commonly known as **Flying fish.**

(2) Body is elongated, measuring about 30–45 cm. in length. The sides of the body are silvery white. Body is divided into **head, trunk** and **tail.**

(3) **Head is blunt** and eyes are large. (4) **Mouth** is wide with teeth in both jaws.

(5) **Body** is covered with overlapping cycloid **scale.**

(6) Lower **pharyngeals** unite as a single bone.

(7) The **dorsal fin** and **anal fin** are short and are supported by soft fin-rays.

(8) **The pectoral fins** are enlarged and in some the lower lobe of **caudal fin** is larger and stronger; and by its powerful strokes the fish is able to leave water with force.

(9) The **pelvic fins** are also developed and adapted for lifting the body.

(10) Tail is **hypoblastic**. Ventral lobe of the tail fin large. Oviparous.

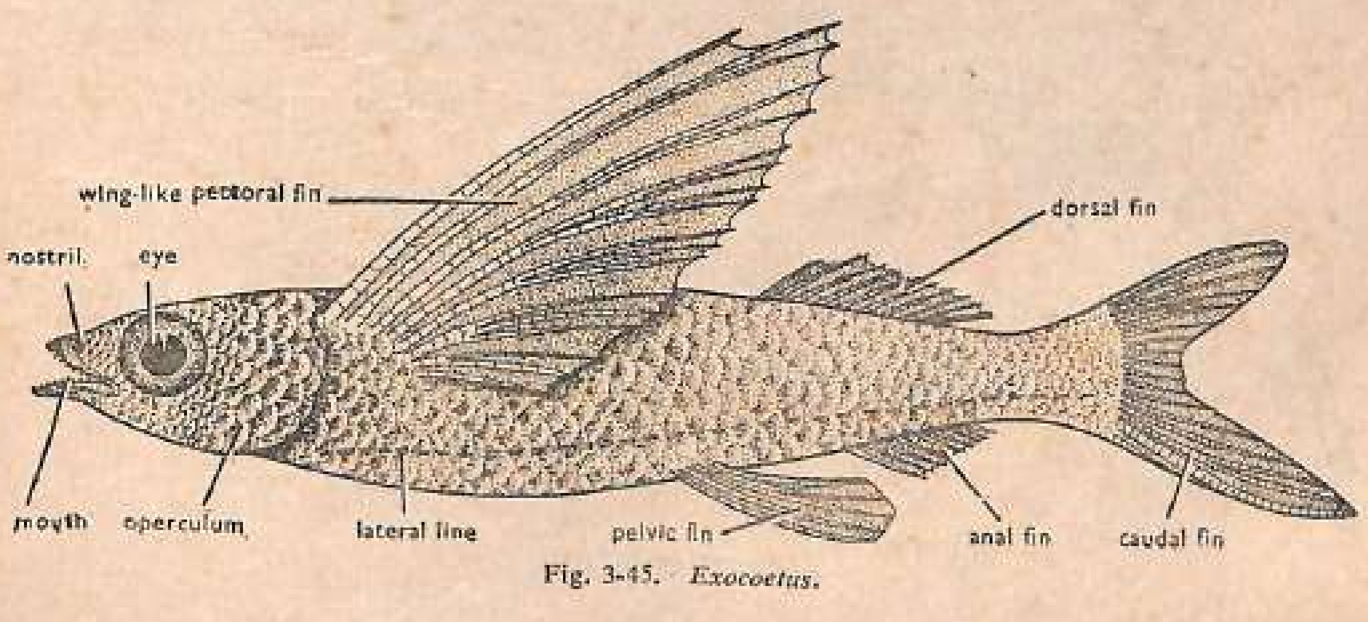


Fig. 3-45. *Exocoetus.*

Special feature—*Exocoetus* is not a true flying fish. Specially in warm sea, it emerges to glide over the water. Pectorals act as wings. It also leaves water to escape from larger fishes, such as Tunas and Mackerels. The flying fish also serves as a food. The fish can glide over the surface of the water for about 400 meters.

Identification—*By large pectoral fins and hypoblastic tail.*

45. Syngnathus

Classification :

Phylum....................**Chordata**
Subphylum....................**Vertebrata**
Superclass....................**Gnathostomata**
Class....................**Osteichthyes**
Subclass....................**Actinopterygii**
Superorder....................**Teleostei**

} Characters same as those of *Labeo*.

Order....................**Solenichthyes** → Pipe-fish and sea horses. Mouth at the end of tubular snout, male with brood pouch and fins minute.

Family....................**Syngnathidae**
Type....................*Syngnathus*.

Geographical distribution—*Syngnathus* is distributed over greater part of the world.

Habit and habitat—*Syngnathus* is found in the Indian Ocean.

Comments :

(1) *Syngnathus* is commonly known as **pipe-fish.**
(2) **Body** is elongated, covered by ring-like exoskeletal rings. Anteriorly head is produced in the form of snout.
(3) **Gills** are reduced. (4) **Dorsal fin** is present, while ventral fins are absent.
(5) **Tail is heterocercal** and slightly **prehensile.** (6) Fish swims in vertical position.
(7) **Oviparous. Fertilization** is external. (8) Males are provided with brood pouch.

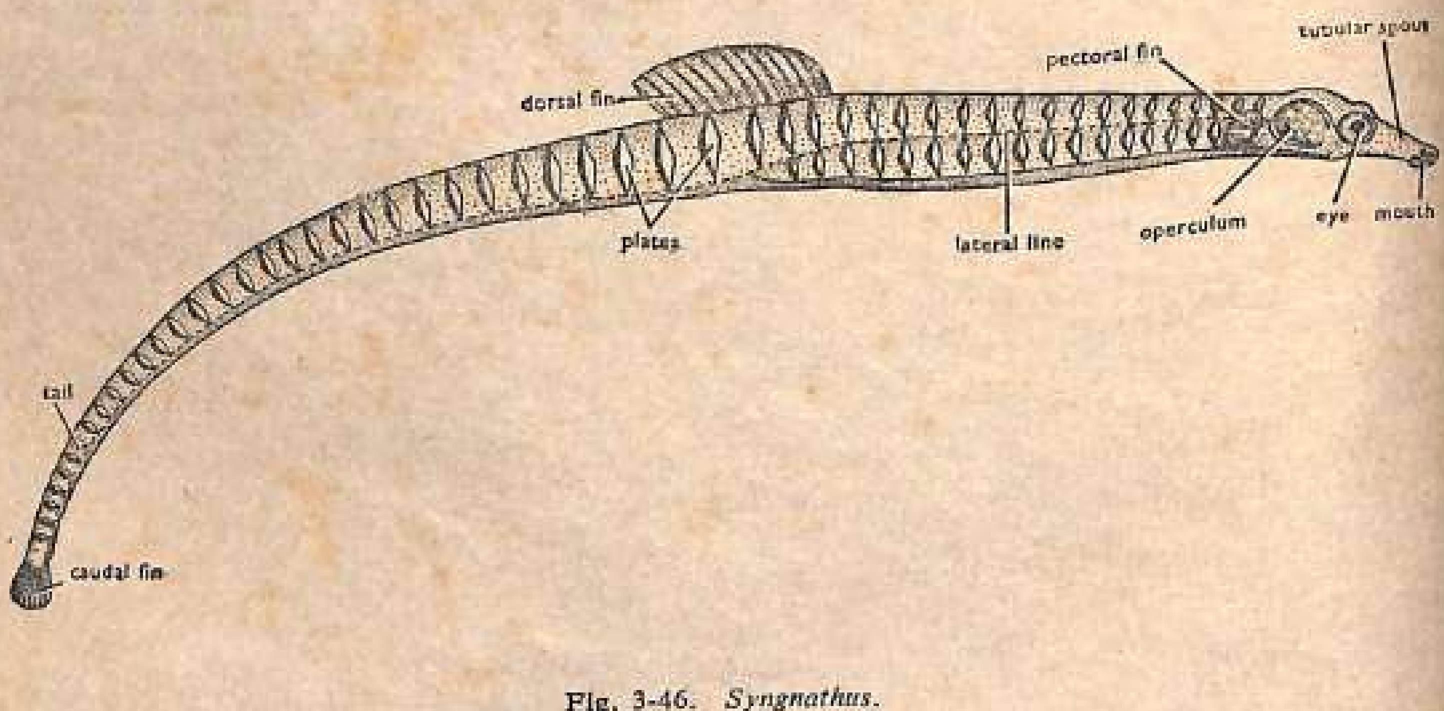


Fig. 3-46. *Syngnathus*.

46. *Hippocampus*

Classification :

Phylum............**Chordata**	Characters same as those of *Syngnathus*.
Subphylum........**Vertebrata**	
Superclass........**Gnathostomata**	
Class................**Osteichthyes**	
Subclass...........**Actinopterygii**	
Superorder.......**Teleostei**	
Order..............**Solenichthyes**	
Family.............**Syngnathidae**	
Type................*Hippocampus*.	

Geographical distribution—*Hippocampus* has cosmopolitan distribution, found in almost all warm sea waters, specially in India, Japan, Malaysia, China and Archipelago. **Cretaceous** to **Recent**.

Habit and habitat—*Hippocampus* is found in the Indian Ocean and is represented by several species. They swim upright, swaying their tails and **gyrating** their trunks in graceful manner, holding a weed with their tails.

Comments :

(1) *Hippocampus* is commonly called as **sea-horse.**

(2) Shape of the body is like horse neck and head. However, body is divided into **head, trunk** and **tail.**

(3) **Head** is produced into **snout. Mouth** is found at the end of the snout. Head has eyes and is backwardly produced into **crest.**

(4) Some species have fine trailing filaments over the body.

(5) Body is covered with ring-like exoskeleton of enlarged soft plates.

(6) **Gill clefts** are reduced to a small opening. Gills are of special type in the form of special tufts and covered by **opercula.**

(7) **Dorsal fin** is single; **ventral** and **caudal fins** are absent.

(8) A pair of small transparent pectoral fins is foun d on either side of head.

(9) In females there is a small anal fin. Males contain br ood pouches, which carry eggs until they hatch.

(10) **Tail** is **prehensile** and **curved.** Entire trunk region and tail are encased in bony and rin g-like plates, and due to rigid exoskeletal armour, the sea-horse swims in upright position.

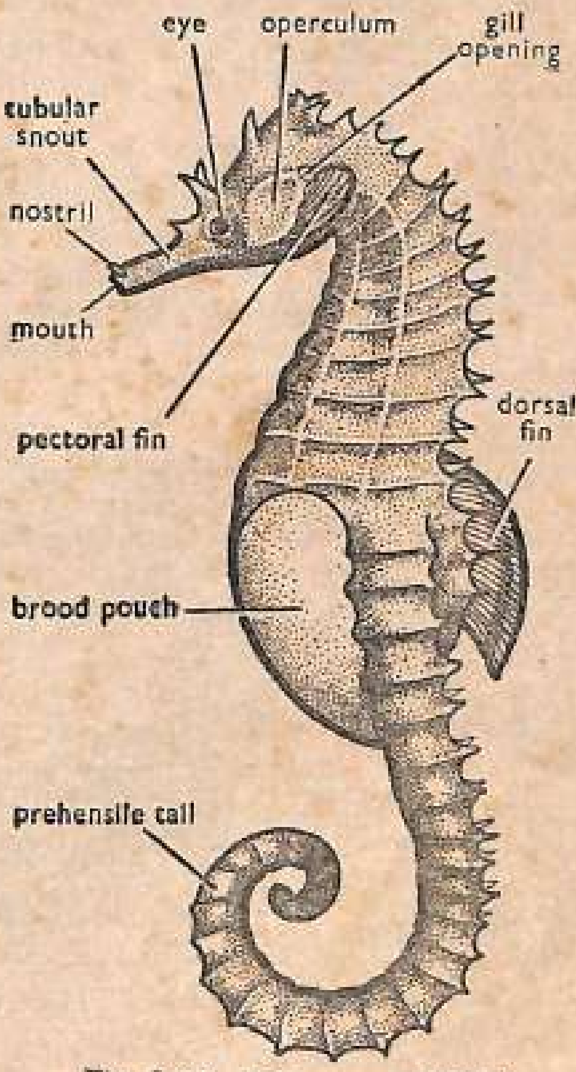


Fig. 3·47. *Hippocampus* (Male).

Special feature—*Hippocampus* is a vertically swimming fish. It has strongly deviated from fish-like appearance with **arching neck** and snout like horse, abdomen like pigeon and prehensile tail like Langur monkey. Sea-horse is a very amusing and most familiar fish.

Identification—*By mere horse-shaped neck and head very easy to recognize.*

47. Echeneis

Classification :

Phylum..................**Chordata**		
Subphylum.............**Vertebrata**		
Superclass..............**Gnathostomata**	}	Characters same as those of *Syngnathus*.
Class......................**Osteichthyes**		
Subclass.................**Actinopterygii**		
Superorder.............**Teleostei**		
Order......................**Discocephali**	→	Dorsal fin modified into adhesive disk, other fins normal and used for ordinary swimming.
Family...................**Echeneididae**		
Type.......................*Echeneis*.		

Geographical distribution—The fish (*Echeneis*) is distributed all over the tropical and warm seas but specially found on the south coast of England.

Habit and habitat—*Echeneis* is a common marine fish. It swims in water feeding on small fishes. It attaches itself by means of its adhesive disk to boats, turtles and other swimming objects.

Comments :

(1) *Echeneis* is commonly called as **sucker-fish**. The **first spinous dorsal fin** is modified into an **adhesive disk or sucker**. By means of sucker it attaches to ships or with skin of other fish. The adhesive disk is composed of several **flat** and bony **plates**, arranged parallel with each other.

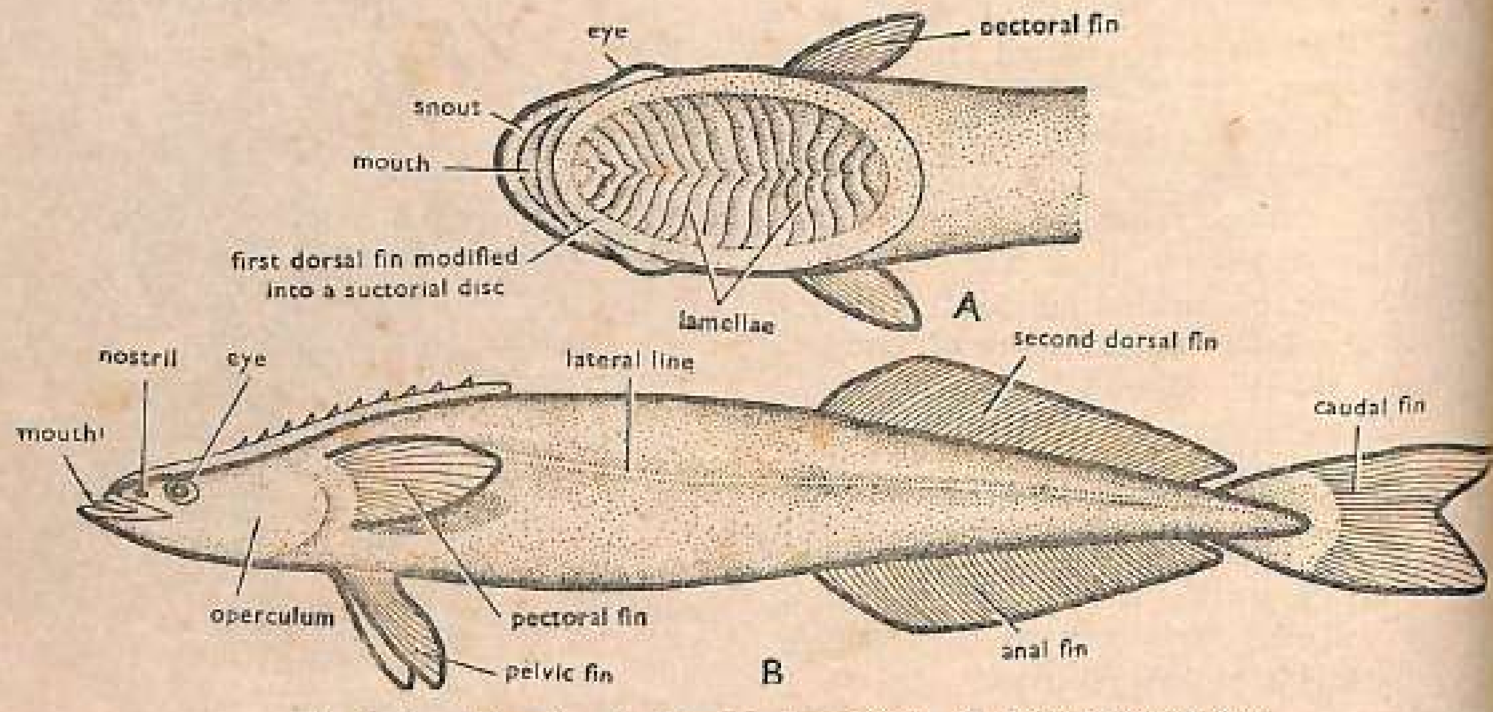


Fig. 3-48. *Echeneis*. A—Head in dorsal view. B—Fish in lateral view.

(2) **Pectoral fin** inserted high up. (3) **Supra-clavicle** is much reduced.

(4) **Ventral fin** is with a spine and 5 rays.

(5) Body is elongated and covered with small scales, measuring about 1 meter in length.

(6) **Pre-caudal** vertebrae with **parapophyses**.

(7) Air bladder absent. (8) Tail homocercal.

(9) Other fins normal and used for swimming. (10) Eyes and nostrils present.

Special feature—The sucker-fishes are employed to catch turtles on the east coast of Africa by the natives. The upper surface of the head contains a **flat oval adhesive disk** which is modified spinous dorsal fin. The disk consists of several lamellae-like structures forming **suctorial funnel**.

48. *Pleuronectes*

Classification :

Phylum..............**Chordata**
Subphylum.........**Vertebrata**
Superclass.........**Gnathostomata**
Class.................**Osteichthyes**
Subclass............**Actinopterygii**
Superorder.........**Teleostei**
} Characters same as those of *Echeneis*.

Order................**Pleuronectiformes** → **Flat-fish.**
Family..............**Pleuronectidae**
Type..................*Pleuronectes*.

Geographical distribution—*Pleuronectes* is found in South America, Malaya and southern hemisphere. **Upper Eocene** to **Recent**.

Habit and habitat—*Pleuronectes* is a marine **bottom dweller** in coastal waters lying on side. It feeds on molluscs.

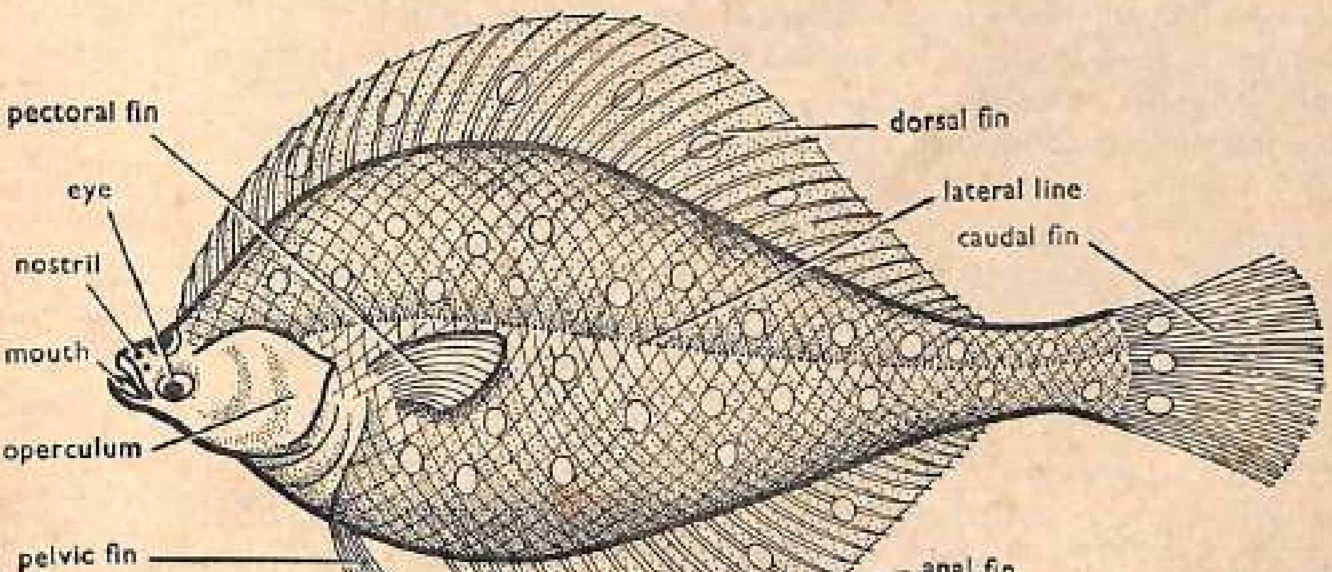


Fig. 3-49. *Pleuronectes*.

Comments :

(1) *Pleuronectes* is commonly called as **flat-fish.**

(2) The fish is **asymmetrically** flattened. The head is asymmetrical, the skull is twisted with two orbits on one side in the adult and hence the fish is **sinistral**. The eyes are found on left side. Body is strongly compressed.

(3) The right side is white and left side is coloured.

(4) The **dorsal** and **anal fins** are elongated, devoid of spines and continuous with the caudal fin. **Pectoral fins** are placed high up.

(5) **Body** is covered by imbricate, **cycloid** or **ctenoid** scales.

(6) Air bladder **physoclistous.** (7) **Spiracle** is absent. (8) **Mouth** is **protractile.**

Special feature—Young *Pleuronectes* is bilaterally symmetrical, but fish soon lies on one side and **lower** eye migrates around so that both eyes are on upper surface. The **flat-fish** is also an important food fish and is sought commercially to a great extent.

49. Lophius

Classification :

Phylum...............**Chordata**
Subphylum..........**Vertebrata**
Superclass..........**Gnathostomata**
Class.................**Osteichthyes**
Subclass.............**Actinopterygii**
Superorder..........**Teleostei**
Order..................**Pediculati**
Family.................**Lophiidae**
Type...................*Lophius*.

Subphylum to Superorder: Characters same as those of *Echeneis*

Order: → Dorsal fin consists of flexible rays with dilated tips.

Geographical distribution—*Lophius* is found in the Atlantic, Indian and Pacific oceans. It also occurs on the coasts of Europe and North America.

Habit and habitat—*Lophius* is a marine seashore fish found upto 60 fathoms. It captures fish, marine invertebrates and birds. Deep-sea Anglers are found at a depth of 1,500 to 6,000 feet.

Comments :

(1) *Lophius* is commonly known as **Angler fish.**

(2) **Body** is depressed, dorsoventrally flattened, ugliest and soft and measuring about 4 feet in length.

(3) The **mouth** is large, containing strong **cordiform** or recurved **teeth.**

(4) **Gill opening** is in lower axil of pectoral fin. (5) **Pseudobranchiae** are present.

(6) Eyes are large and lateral in position; nostrils small.

(7) The first dorsal fin is greatly modified. Its first three **spines** are not united by fold of skin and the first spine becomes rod-like and bears a fleshy mass or **bait at its tip.** The bait is used to attract other fishes and small worms. When any curious and hungry animal comes near bait, it is ferociously attacked and eaten by Angler fish. The bait is called as **illicium.**

(8) Next 3 spines are united by a fold, while rest of the dorsal fin is supported by soft rays.

(9) **Pectoral** and caudal fins present.

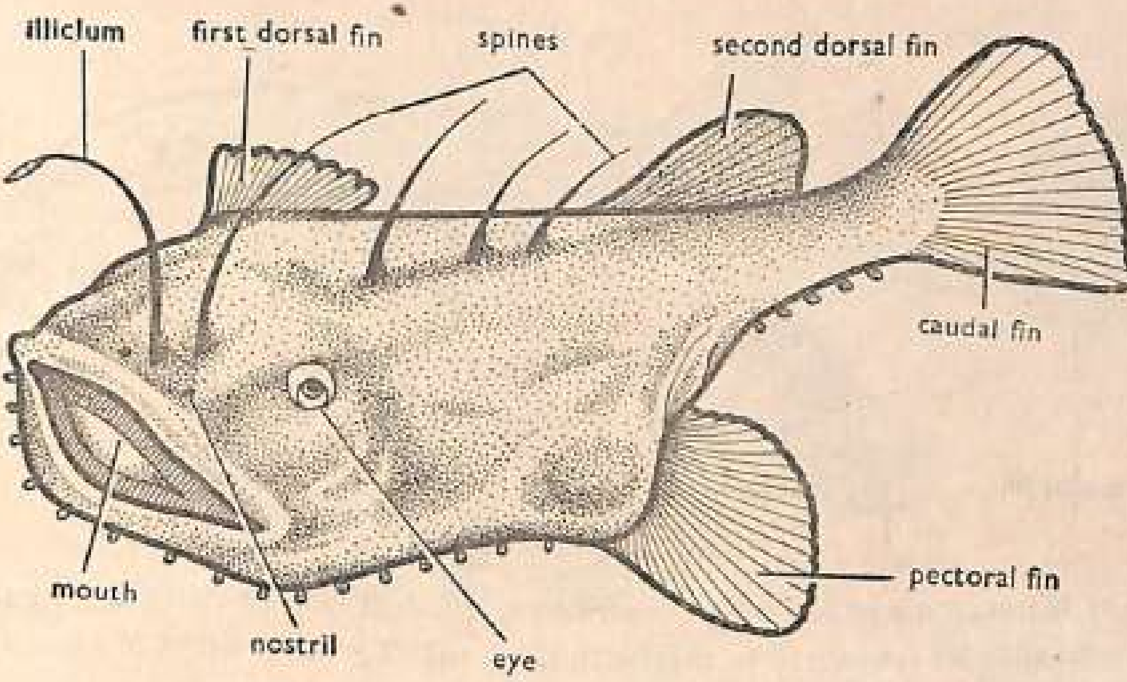


Fig. 3-50. *Lophius*.

(10) The male is small in size and attached to the body of the female as parasite.

Special feature—*Lophius* is deep-sea fish with modified dorsal fin as bait. Some of them contain luminous bulbs i.e. they are **bioluminescent.** The minute male attaches permanently to the female, their bodies and blood streams growing together and such parasitism is probably an adaptation to ensure mating in the dark depths of the sea.

Identification—*By wide mouth and modified bait-like dorsal fin.*

50. *Tetradon*

Classification :

Phylum..........**Chordata**	
Subphylum.....**Vertebrata**	Characters same as those of *Echeneis*.
Superclass.....**Gnathostomata**	
Class...........**Osteichthyes**	
Superclass......**Actinopterygii**	
Suborder........**Teleostei**	
Order...........**Plectognathi**	→ Body globose, jaws short, teeth strong incisors, scales bony or spiny and gill clefts small.
Family..........**Tetradontidae**	
Type............***Tetradon.***	

Geographical distribution—*Tetradon* is distributed in the Indian Ocean, Malaya Archipelago and U.S.A.

Habit and habitat—*Tetradon*

Comments :

(1) *Tetradon* is commonly called as **globe fish** or **puffers**.

(2) The **colour** of the body is light brown along the back and dark brown bands are found from the back upto the sides.

(3) From snout to dorsal fin oval light spots are found in large numbers.

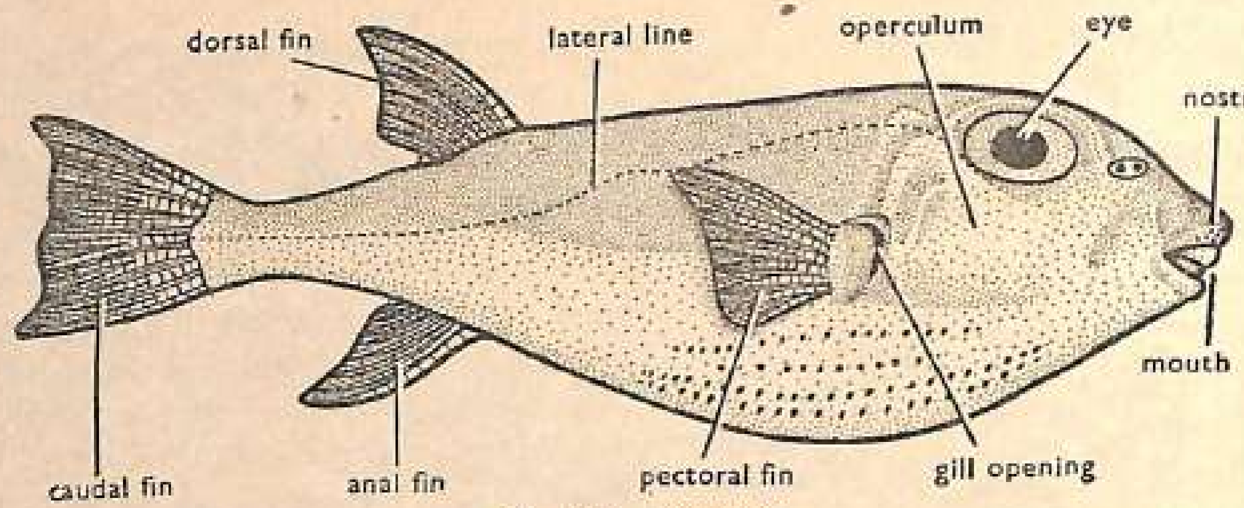


Fig. 3-51. *Tetradon.*

(4) **Body** is rounded and can adapt according to need; it may be flattened or balloon-like.
(5) **Pre-maxillaries** are united to maxillaries. (6) **Teeth** are fused to form a beak.
(7) There is one nasal opening on either side, found on a papilla.
(8) **Spinous dorsal fin** and **ventral fin** are absent.
(9) **Abdomen** contains dilatable sac. (10) Air bladder is horseshoe-shaped.
(11) **Body** is covered with small spiny, sub-imbricate bony **laminae**. Eyes large.

Special feature—The fish has commercial and medicinal value. The Japanese use the dried skin of the fish in making lanterns. Fish is also prescribed in diets in lung infections.

Identification—*By bony sub-imbricate laminae.*

51. *Diodon*

Classification :

Phylum............**Chordata**
Subphylum.......**Vertebrata**
Superclass.......**Gnathostomata**
Class...............**Osteichthyes**
Subclass...........**Actinopterygii**
Superorder.........**Teleostei**
Order...............**Plectognathi**

(Subphylum to Order:) Characters same as those of *Tetradon*.

Family............**Diodontidae**
Type...............***Diodon.***

Geographical distribution—*Diodon* is confined to tropical seas.

Comments :

(1) *Diodon* is commonly known as **Porcupine fish.**
(2) **Body** is rounded, globose and covered with numerous **flexible spines**. The spines are organs of defence; they are erected to protect from enemy. Some forms inflate their bodies by swallowing water.
(3) The **teeth** are strong incisors, forming sharp edged **beak.**

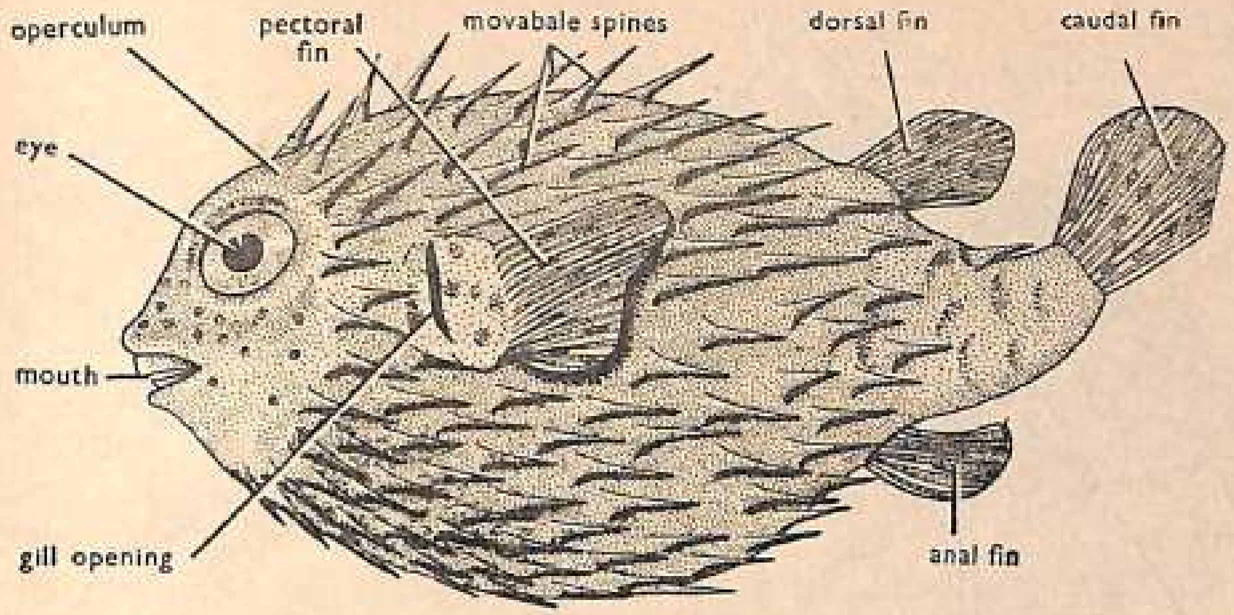


Fig. 3-52. *Diodon.*

(4) **Inter-operculum** is rod like and attached to the anterior limb of sub-operculum.

(5) **Gills** are three in number. (6) **Pre-caudal** vertebrae contain bifid neural spines.

(7) **Belly** is inflatable. (8) Vertebrae are 21 or 22 in number.

(9) **Scales** generally spiny or bony.

(10) **Skin leathery; anal** and **dorsal** fins small, caudal fin slightly upwards and tail literally absent.

Special feature—The porcupine fishes are poisonous and non-edible. They attracted attention of the earliest times, as they were frequently preserved as 'curiosities'.

Identification—*By flexible spines and globose body.*

52. *Ostracion*

Classification :

Phylum............**Chordata**		
Subphylum.......**Vertebrata**		
Superclass.......**Gnathostomata**	}	Characters same as those of *Tetradon.*
Class..............**Osteichthyes**		
Subclass..........**Actinopterygii**		
Superorder........**Teleostei**		
Order..............**Plectognathi**		
Family.............**Ostraciontidae**		
Type...............*Ostracion.*		

Geographical distribution—*Ostracion* is chiefly distributed in tropical seas, in Red Sea, African sea, the Indian Ocean and Malaysian Archipelago.

Habit and habitat—*Ostracion* is found in the bottom of shallow sea water.

Comments :

(1) *Ostracion* is commonly known as **Trunk fish** or **Coffer fish**.

(2) **Body** is not elongated and is encased in a **carapace**, composed of large, **juxtaposed** and hexagonal **bony plates.** Body is roughly triangular.

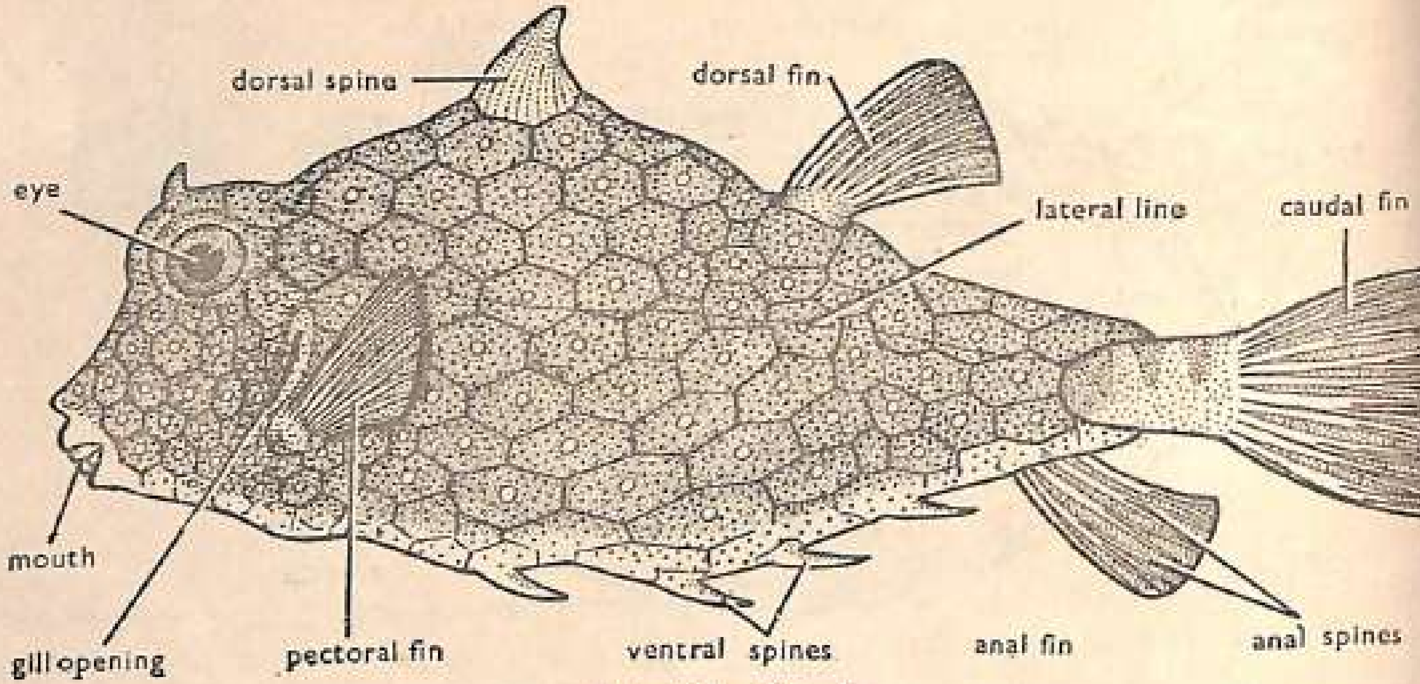


Fig. 3-53. *Ostracion.*

(3) **Post-clavicles** are much expanded; **teeth** incisor like and **palatine** immovable.

(4) **Spiny dorsal** fin and ventral fin are absent.

(5) **Pectoral fin** is enlarged and helps to form water current.

(6) **Caudal fin** acts as a **rudder** during rapid swimming.

(7) The **colour** of the body is olive brown with dark bands. A light **blue spot** is present in the centre of each scute or bony plate.

(8) A compressed and small **supra-orbital spine**, directed upwards and backwards, is present above orbit.

Identification—*By bony plates.*

53. *Protopterus*

Classification :

Phylum............**Chordata**		Characters same as those of *Labeo* or previous fish.
Subphylum.......**Vertebrata**		
Superclass.......**Gnathostomata**		
Class..............**Osteichthyes**		
Subclass..........**Choanichthyes**	→	Nostrils connected to mouth cavity, paired fins with larger median lobe.
Superorder......**Dipnoi** (Dipneusti)	→	Lung fish. Body long and slender. Premaxilla or maxilla absent, air bladder lung like, Devonian to Recent.
Order.............**Lepidosireniformes**	→	Body eel like, scales small, burrowing fish.
Type..............*Protopterus* (African lung fish).		

Geographical distribution—*Protopterus* has wide distribution. It is found in the great African continent, the Nile, Congo basin, Lake Tanganyika. **Devonian** to **Recent**.

Habit and habitat—The fish is adapted for burrowing life. It lives in burrows made in muddy water. In dry season, they retire to vertical burrows (nest) in mud lined with mucus.

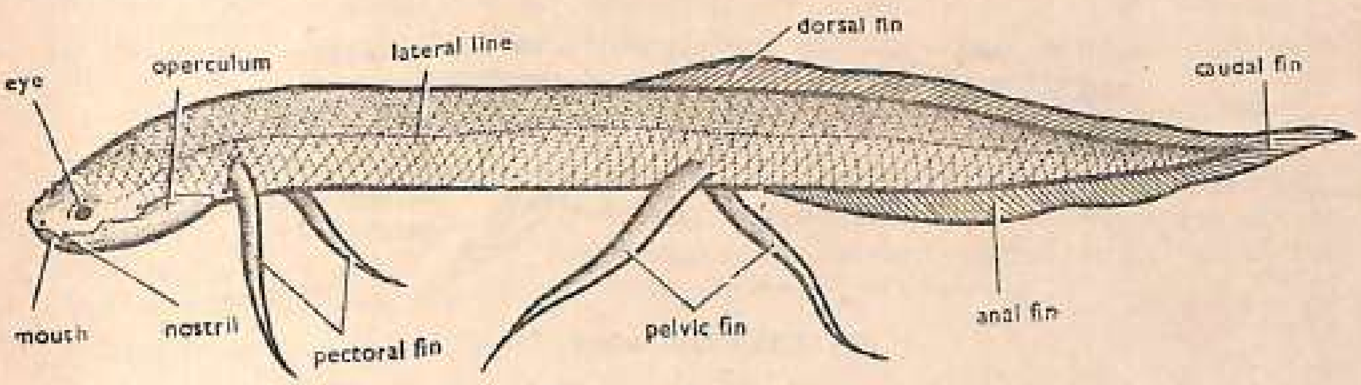


Fig 3-54. *Protopterus.*

Comments :

(1) Body is elongated, cylindrical, **eel like** and is completely enclosed by **cycloid** scales.

(2) Head contains small **eyes, nostrils** and **mouth**.

(3) **The dorsal** and **caudal fins** are continuous.

(4) The **pectorals** and **pelvic fins** are reduced to **slender appendages** and without fin rays.

(5) There are six **branchial arches** and five clefts.

(6) The larval **gills** are retained as vestigial organs throughout life.

(7) There are **two lungs** extending throughout body cavity.

(8) Fish comes on surface to engulf air. (9) Lateral line well developed.

Special feature—*Protopterus* in an air-breather fish. *Protopterus annectens* and 2 other species of Central Africa retire to burrows in mud, where mucus dries up to form **"cocoon"** with lid and a tube leading to mouth of the fish for breathing. It spawns after return of water.

Identification—*By slender modified appendages.*

54. *Lepidosiren paradoxa*

Classification : Same as those of *Protopterus.*

Geographical distribution—*Lepidosiren* is distributed in Amazon and Paraguay basins and plains of South America.

Habit and habitat—*Lepidosiren* inhabits swampy places. It makes burrow lined by mucus in muddy water.

Comments :

(1) *Lepidosiren* is commonly called as **South American lung fish.**

(2) Body is elongated and **eel-like,** measuring 3 feet in length and covered with **cycloid** scales.

(3) **Gill slits** are 4 in number. (4) **Eyes** are comparatively reduced.

(5) The **paired fins** are reduced to slender **styliform appendages** formed of jointed axis.

(6) During breeding season **vascular filaments** develop on the pelvic fins of the male. The filament is considered to be respiratory.

(7) The fish has **two lungs.** (8) **Glottis** is provided with a movable epiglottis.

(9) **Caudal fin** and **anal fin** continuous. (10) Lateral line present.

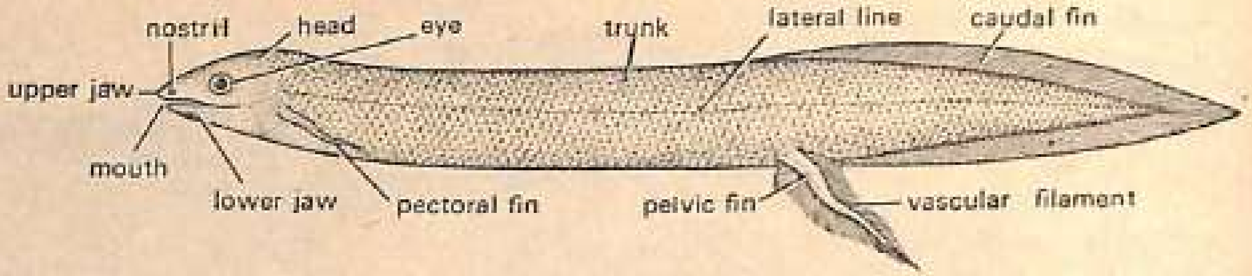


Fig. 3-55. *Lepidosiren.*

Special feature—*Lepidosiren* shows **parental care forming L-shaped nests.** The fish aestivates in mud during dry season, but it has no cocoon formation habit.

Identification—*By reduced styliform paired appendages.*

55. *Neoceratodus*

Classification :

Phylum............**Chordata**		
Subphylum........**Vertebrata**		
Superclass........**Gnathostomata**		Characters same as those of *Protopterus*.
Class..............**Osteichthyes**		
Subclass..........**Choanichthyes**		
Superorder.......**Dipnoi**		
Order..............Neoceratodiformes		
Type..............*Neoceratodus*.		

Geographical distribution—*Neoceratodus* is found in Buret and Mary rivers of Australia and in Queensland. **Triassic** to **Cretaceous.**

Habit and habitat—*Neoceratodus* inhabits quiet pools that become stagnant during dry season, when the fish rises to the surface to engulf fresh air into lungs. It **feeds** on small crustaceans and worms.

Comments :

(1) *Neoceratodus forsteri* is commonly called as **Australian lung fish** (barramunda).

(2) Body is **elongated,** measuring 1–2 meters and covered with distinct large overlapping cycloid scales.

(3) **Mouth** is small.

(4) **Paired fins** placed low, **pectorals** near the head and **pelvics** near the tail.

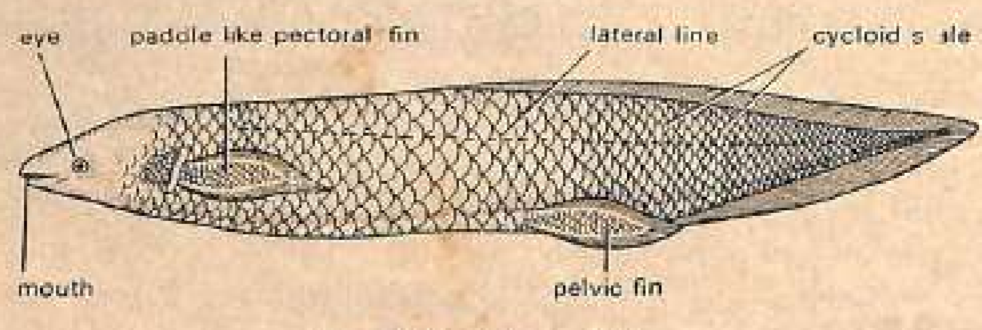


Fig. 3-56. *Neoceratodus.*

(5) Fins leaf-like or **paddle-like** and **archipterygical.** (6) **Tail is diphycercal.**

(7) **Plumonary vasculated air bladder** (**lung**) opens into the oesophagus by a long duct.

(8) Lung not bilobed. (9) Eyes small. (10) Lateral line present.

(11) There is no larval stage and hibernation.

Special feature—*Neoceratodus forsteri* is the only living species and is considered as **living fossil.** The paired fins are modified into paddles. The skeleton of these fins is peculiar, because in each fin there is a central axis bearing radials of different sizes on both sides. The internal surface of the lung is sacculated and contains a series of alveoli. Lung respiration supplements gill respiration.

Identification—*By paddle-like paired appendages.*

F. MUSEUM SPECIMENS OF CLASS AMPHIBIA

NATURAL HISTORY

Amphibians mainly live in water or damp places; none in salt water. They are the commonest in moist temperate regions but some are tropical; one frog ranges into Arctic Circle and tree frogs occur above 12,000 feet in Sierra Nevada of Californi . Some toads are tree toads and live in deserts, some are nocturnal. The hell bender (*Cryptobranchus*), mud puppy (*Necturus*) and Congo eel (Amphiuma) are strictly aquatic. Some frogs are purely arboreal. Land salamanders hide under stones and logs. Amphibians partly pass their life in water and partly on land (Gr., *amphi*=dual; *bios*=life). They are the lowest and earliest tetrapod evolving from Devonian and onwards. Amphibians have educational, experimental and food value.

Outline Classification of Amphibia

It is divided into the following orders—

Order 1.........**Stegocephalia**

Order 2.........**Labyrinthodontia** *e.g., Eryops.*

Order 3.........**Gymnophiona** or **Apoda** *e.g., Ichthyophis, Gymnophis, Uraeotyphlus.*

Order 4.........**Urodela** or **Caudata**—It is divided into the following suborders :

- (*a*) *Suborder*......**Proteida** *e.g., Necturus, Proteus, Triton.*
- (*b*) *Suborder*......**Cryptobranchoidea** *e.g., Cryptobranchus.*
- (*c*) *Suborder*......**Ambystomoidea** *e.g , Ambystoma.*
- (*d*) *Suborder*......**Salamandroidea** *e.g., Salamandra, Triturus.*
- (*e*) *Suborder*......**Amphiumoidea** *e.g., Amphiuma.*
- (*f*) *Suborder*......**Meantes** or **Sirenidea** *e.g., Siren.*

Order 5.........**Salientia** or **Anura**

- (*a*) *Suborder*......**Amphicoela**
  - *Family*...**Ascaphidae** *e.g , Ascaphus, Liopelma.*
- (*b*) *Suborder*......**Opisthocoela**
  - (*i*) *Family*....**Discoglossidae** *e.g., Discoglossus, Bombina* and *Alytes.*
  - (*ii*) *Family*...**Pipidae** *e,g., Pipa, Xenopus.*
- (*c*) *Suborder*......**Anomocoela**
  - *Family*...**Pelobatidae** *e.g., Pelobates, Scaphiopus.*
- (*d*) *Suborder*......**Procoela**
  - (*i*) *Family*...**Palaeobatrachidae** *e.g., Palaeobatrachus.*
  - (*ii*) *Family*...**Bufonidae** *e.g., Bufo, Leptodactylus.*
  - (*iii*) *Family*...**Brachycephalidae** *e.g., Brachycephalus.*
  - (*iv*) *Family*...**Hylidae** *e.g., Hyla, Gastrotheia.*
- (*e*) *Suborder*......**Diplasiocoela**
  - (*i*) *Family*...**Ranidae** *e.g., Rana.*
  - (*ii*) *Family*...**Polypedatidae** *e.g., Rhacophorus.*
  - (*iii*) *Family*...**Microhylidae** *e.g., Microhyla.*

56. *Ichthyophis*

Classification :

Phylum............**Chordata**	→	Dorsal tubulated nerve cord, notochord and gill slits present.
Subphylum.......**Vertebrata**	→	Internal skeleton of cartilage or bone, spinal cord forming main axis and composed of overlapping vertebrae, nervous system dorsal to alimentation, complex brain, red blood and two pairs of appendages.
Superclass.......**Gnathostomata**	→	Jaws and paired appendages present.
Class..............**Amphibia**	→	Coldblooded, scaleless glandular skin, can live in water and land, two occipital condyles, heart three chambered and non-marine.
Order.............**Gymnophiona or Apoda**	→	Vermiform Amphibia without limbs or limb girdles.
Type............ ..*Ichthyophis.*		

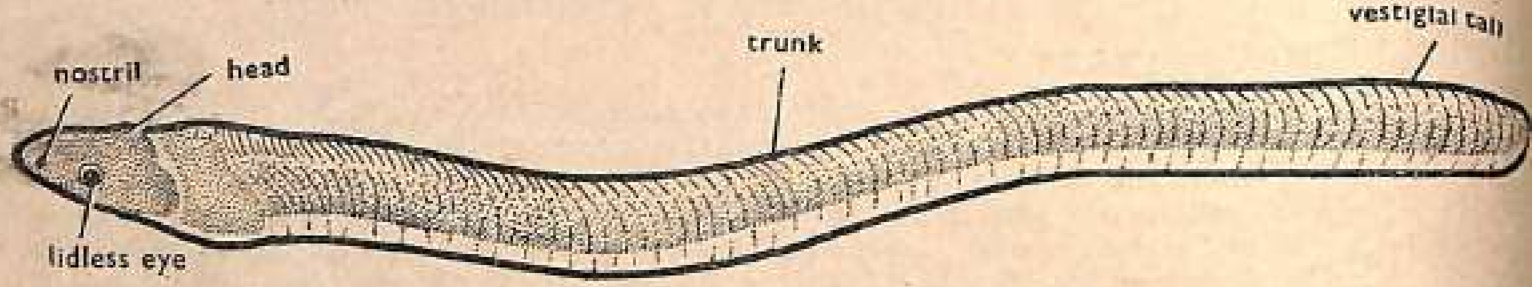


Fig. 3-57. *Ichthyophis.*

Geographical distribution—*Ichthyophis* is distributed in tropical regions and found in India, Sri Lanka, Philippines, Borneo, Java, Scychelles, and Mexico to Argentina.

Habit and habitat—*Ichthyophis* live, burrow and lead a fossorial life in moist ground. The animal is blind and adapted for burrowing life. It feeds on invertebrates.

Comments :

(1) *Ichthyophis* is commonly called as **caecilian.**

(2) Body is worm-like and slender, measuring about 30 cm. in length.

(3) Body is covered with minute scales which are concealed in skin.

(4) **Limbs** and **limb girdles** are absent.

(5) **Skin** smooth with transverse furrows and both **slime glands** and **squirt glands** are present. Squirt glands discharge irritating fluid.

(6) **Skull** compact, roofed with bone.

(7) Head contains eyes, nostrils and a pair of sensory tentacles. **Tympanic** membrane, **tympanic cavity** and **columella** absent.

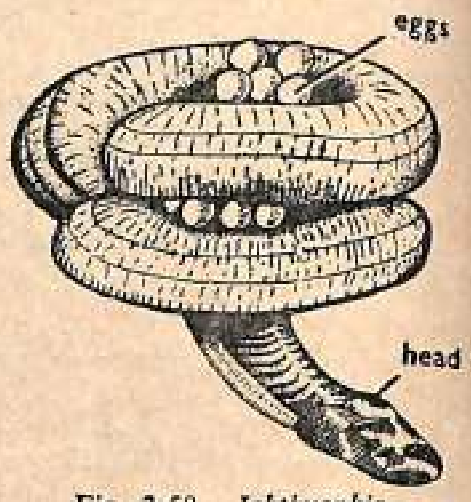


Fig. 3-58. *Ichthyophis.* Female guarding its eggs.

(8) **Eyes** lidless, often beneath skin or maxillary bone. A small protrusible tentacle is present between eye and nostril.

(9) The laryngotracheal chamber is prolonged into a distinct **trachea**. Right **lung** is elongated, while left lung is reduced.

(10) **Vertebrae** are many and **amphicoelus. Anus** is sub-terminal.

(11) **Males** are provided with eversible **copulatory** organ, which shows advanced characters. **Fertilization internal.** Female's cloaca is everted like copulatory organ; eggs are laid in moist burrows. Mother coils around eggs till they hatch into **tadpoles.**

Special feature—The *Ichthyophis* **resembles Amphibia** in having a **3-chambered heart, conus arteriosus, urino-genital** organs and **brain** like Amphibia, but it differs from living Amphibia in having **scales** in **dermis, meroblastic** eggs and larvae without gills. The animal also shows parental care, as the females take care of the eggs till they hatch.

57. *Uraeotyphlus*

Classification : Same as those of *Ichthyophis*.

Geographical distribution—*Uraeotyphlus* has been reported from India, Malaya, South Africa and South America.

Habit and habitat—*Uraeotyphlus* also burrows in moist ground. It feeds on small worms.

Comments :

(1) *Uraeotyphlus* is worm-like and elongated.

(2) **Limbs** are reduced due to burrowing habit.

(3) **Head** is small, **body** is elongated vermiform, which is covered with naked skin.

(4) Several small **dermal scales** are embedded in the skin.

(5) **Eyes** are non-functional, indistinct and concealed beneath the slimy skin.

(6) Between eyes and nares, a sensory pit-like structure is present.

(7) **Dorsal** side is dark green and ventral side white.

(8) Respiration through lung. Right lung is exceptionally large and sac-like.

(9) **Tail** is extremely short. **Anus** sub-terminal.

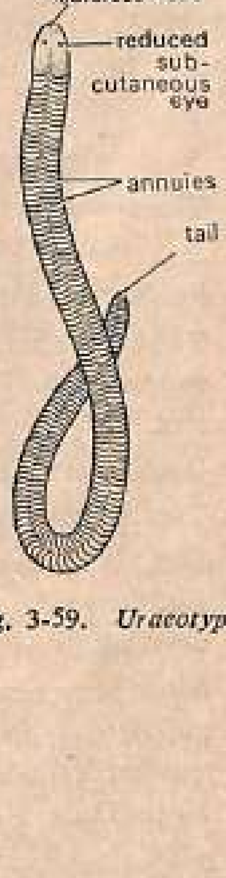


Fig. 3-59. *Uraeotyphlus*.

58. *Necturus*

Classification :

Phylum..................**Chordata**		
Subphylum............**Vertebrata**		
Superclass.............**Gnathostomata**	}	Characters same as those of *Ichthyophis*.
Class......................**Amphibia**		
Order.......................**Urodela or Caudata**	→	Scaleless Amphibia having well developed tail, generally with two limbs, with or without external gills and gill slits in adults.
Suborder..............**Proteida**	→	Body depressed, tail with fin, gills permanent, eyelids absent, lungs present and permanently aquatic.
Family.....................**Proteidae**		
Type.......................***Necturus.***		

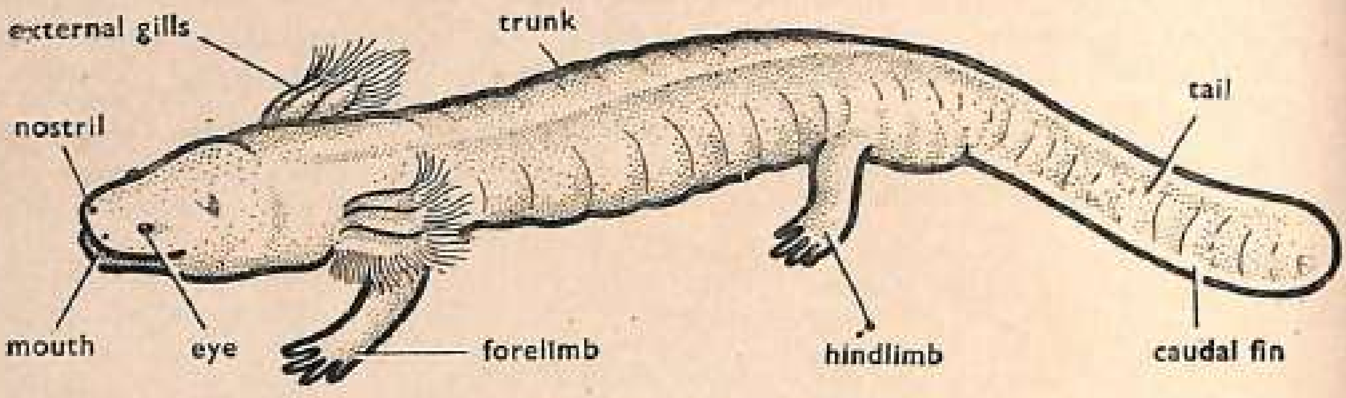


Fig. 3-60. *Necturus.*

Geographical distribution—*Necturus* is found in North America and chiefly in Arkansas river, Carolina and Hudson rivers. **Cretaceous to Recent.**

Habit and habitat—*Necturus* is an aquatic salamander of rivers and lakes of U.S.A. It is a crawling animal on the bottom. It eats small fishes and invertebrates.

Comments :

(1) *Necturus maculosus* is commonly called as **Mud puppy** or **Water dog.**

(2) Body of the animal is **rusty brown** with **blackish spots** and measuring about 30–40 cm. in length.

(3) The **head** is depressed and demarcated from the trunk by a constriction.

(4) The **limbs** are short and weak and provided with four digits only. First digit is lost, limbs are adapted for crawling only.

(5) The tail is laterally compressed and provided with tail fin. It is the main organ of progression. The limbs are meant for crawling only on the bottom of the rivers and lakes.

(6) Eyelids are absent and eyes are small.

(7) **Tympanum** and organs of Jacobson absent; lungs present.

(8) Behind the head on each side there are three **bushy-red coloured**, distinct external gills. Besides external gills there are two gill slits on each side. Breathing is by only external gills.

(9) Mud puppy mates in autumn when females take up spermatophores deposited by males; lay eggs in May or June, 18 to 180 eggs in **nests** attached individually by jelly stalks to undersides of stones. Nests are guarded by females. Eggs hatch in 38 to 63 days into a larva, which matures in 6 years to full size.

Special feature—The adult is supposed to be permanently **neotenic larva** with three pairs of external gills, two pairs of gill slits, lateral line, cartilaginous skull, with larval circulatory system and without Jacobson's organ. Experimentally, metamorphosis in *Necturus* could not be induced. It is a very interesting and favourite animal.

Identification—*By 3 pairs of external gills.*

59. *Proteus*

Classification :

Phylum......................**Chordata**
Subphylum..................**Vertebrata**
Superclass..................**Gnathostomata**
Class..........................**Amphibia**
Order..........................**Urodela**
Suborder....................**Proteida**
Family........................**Proteidae**
Type............................*Proteus.*

} Characters same as those of *Necturus.*

Geographical distribution—*Proteus* is distributed in South-eastern Europe, Austria and Germany. **Eocene to Recent.**

Habit and habitat—*Proteus* inhabits in the waters of **deep cave** in perfect darkness in the underground streams. The temperature never exceeds more than 50°F. It feeds on small crustaceans.

Comments :

(1) *Proteus* is commonly known as **olm** or **cave salamander.**
(2) Body of the animal is elongated, measuring 20–25 cm. in length and is covered with unpigmented skin.
(3) **Head** is broad and **rudimentary eyes** are sunken deep in the head without eyelids.
(4) **Gill slits** are two in number. **Lungs** are present.
(5) **Limbs** are poorly developed, a hind limb contains 2 digits and a forelimb 3 digits.
(6) **Locomotion** by the flattened and **finned tail** which is compressed and provided with **caudal fin.**
(7) **Skull cartilaginous.** Both jaws have teeth.
(8) Three pairs of **carmine-coloured** external gills are persistent. The animal often rises to the surface, gives out a bubble of air and engulfs fresh air in lungs.

Special feature—*Proteus* is a permanent neotenic larva with 3 pairs of gills.

Identification—*By gills, limbs and caudal fin.*

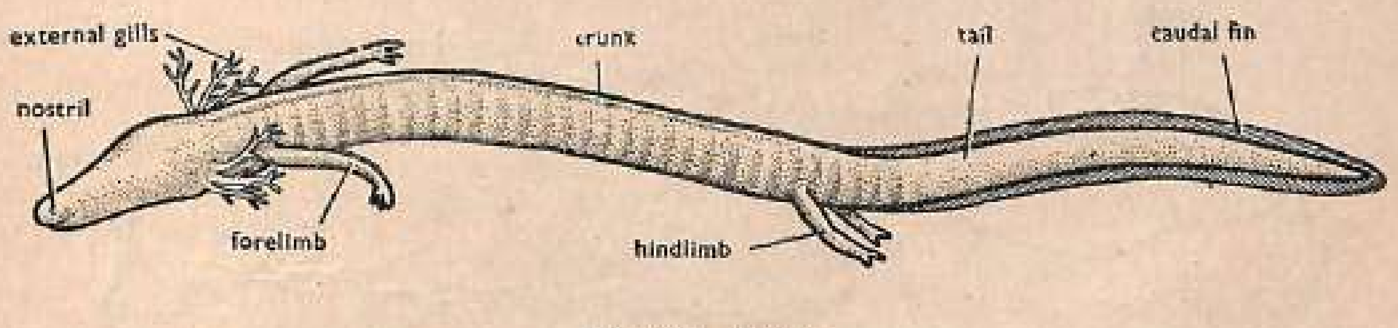


Fig. 3-61. *Proteus.*

60. *Cryptobranchus*

Classification :

Phylum............**Chordata**
Subphylum.......**Vertebrata**
Superclass.......**Gnathostomata**
Class..............**Amphibia**
Order.............**Urodela**
} Characters same as those of *Necturus*.

Suborder.........**Cryptobranchidea** → **Body depressed, skin soft, flabby with fleshy folds, eyelids absent, permanently aquatic. Oligocene to Recent.**

Family............**Cryptobranchidae**
Type...............*Cryptobranchus*.

Geographical distribution—*Cryptobranchus* is commonly found from Louisiana (America) to Ohio (Japan), in Eastern Asia, and New York. **Miocene** to **Recent**.

Habit and habitat—*Cryptobranchus* is found in running water with rock slabs. It feeds on small worms, small fishes and crustaceans.

Comments :

(1) *Cryptobranchus* is commonly known as **hell bender.**

(2) Body is elongated and depressed measuring 60 cms.

(3) Skin is soft, flabby with fleshy folds at sides.

(4) Head is broad. (5) Eyes are small without eyelids.

(6) Gills absent in adults; but the first gill cleft or spiracle remains open and acts as excurrent opening for the water taken into the mouth during buccal respiration.

(7) Vomerine teeth are parallel to jaws.

(8) Angular and pre-articular of lower jaw are separate.

(9) Sexes are separate. (10) Spermatophores are absent.

(11) Fertilization is external and breeding season is late summer; females lay eggs about 300 in number in rosary-like strings. The larvae hatch in November and take several years to mature.

Special feature—*Cryptobranchus* has primitive features, such as open spiracle, absence of gills and presence of 4 epibranchials.

Identification—*By side skin fold.*

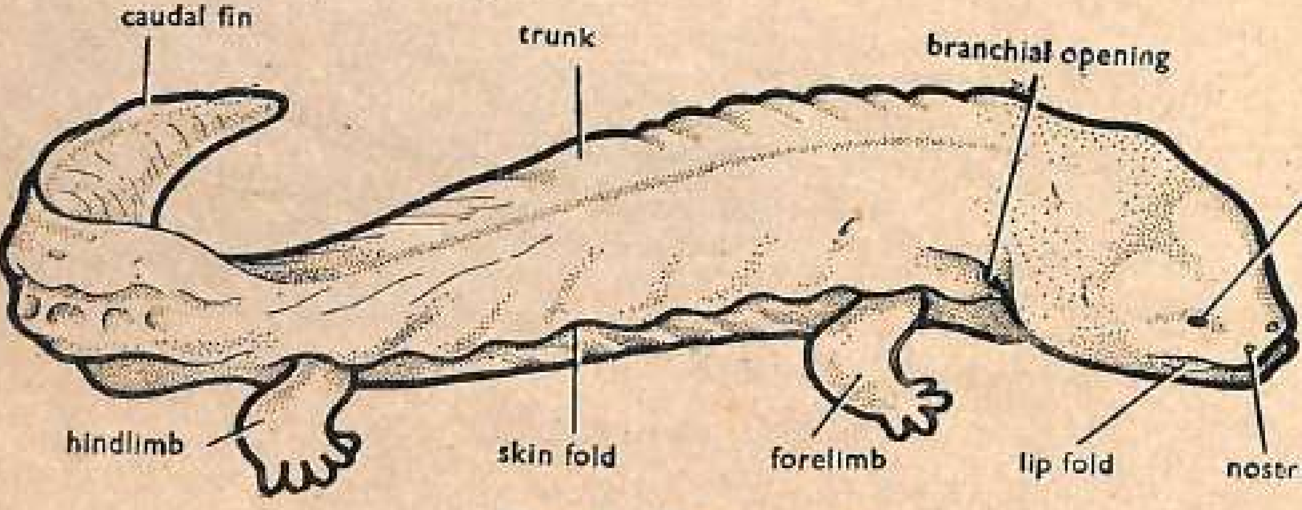


Fig. 3-62. *Cryptobranchus*.

61. *Ambystoma*

Classification :

Phylum..................**Chordata**		
Subphylum..............**Vertebrata**		
Superclass..............**Gnathostomata**	}	Characters same as those of *Necturus*.
Class.....................**Amphibia**		
Order....................**Urodela**		
Suborder................**Ambystomoidea**	→	Teeth in transverse row across posterior margins of vomers, none on palatine bones, eyelids present and vertebrae amphicoelus.
Family...................**Ambystomidae**		
Type......................*Ambystoma*.		

Geographical distribution—*Ambystoma* adult is terrestrial, found in North America, Central Mexico and the United States. **Upper Cretaceous** to **Recent**.

Comments :

(1) *Ambystoma* is commonly known as **Tiger salamander** or **Spotted salamander**.

(2) **Body is lizard-like**, having transverse grooves and is measuring 18-20 cm. in size.

(3) The Spotted salamander (*A. maculatum*) has round yellow and orange spots over body, while **Tiger salamander** (*A. tigrinum*) has more **spots** extending over belly.

(4) The **external gills** and **tail fin** are absent.

(5) **Head** is depressed with large **mouth** and contains eyes and a pair of **poison glands**, called as **paratoids**.

(6) **Prevomers** short and devoid of posterior processes, teeth across rear margins of vomers. No teeth on palatine.

(7) **Eyelids** and lungs are present. (8) **Vertebrae amphicoelus**.

(9) The limbs are well developed; forelimbs and hind limbs contain 4 and 5 digits respectively.

(10) **Sexes** are separate. Fertilization internal.

(11) *Ambystoma* lays eggs near pond. The eggs develop into larva, known as **Axolotl larva**.

Special feature—The **axolotl** larva is famous for neoteny.

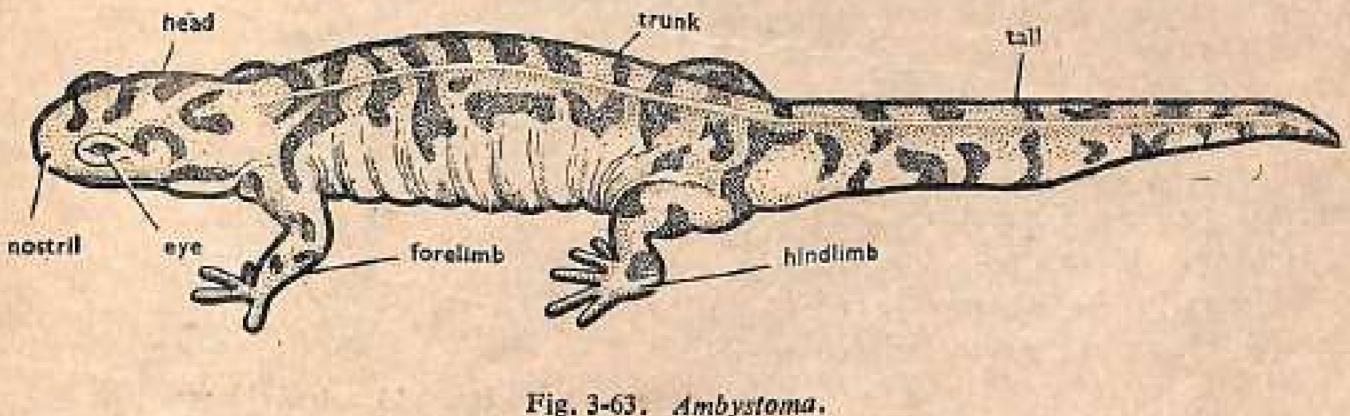


Fig. 3-63. *Ambystoma*.

62. Axolotl Larva

Classification :

Phylum.....................	**Chordata**	Characters same as those of *Ambystoma*.
Subphylum.....................	**Vertebrata**	
Superclass.....................	**Gnathostomata**	
Class.....................	**Amphibia**	
Order.....................	**Urodela**	
Suborder.....................	**Ambystomoidea**	→ Teeth in transverse row across posterior margins of vomers, none on palatine bones, eyelids present and vertebrae amphicoelus.
Family.....................	**Ambystomidae**	
Type.....................	***Axolotl larva***	

Comments :

(1) The *axolotl larva* was previously considered as adult form and called as *Siredon*. Later on, it was found to be larva of *Ambystoma*.

(2) The **larva** has three pairs of **external gills** and four pairs of open **gill clefts**.

(3) The larva is **perennial**, measuring about 10½ inches in length. The larval body is divided into **head**, **trunk** and **tail**. Tail is provided with caudal fin.

(4) It becomes sexually mature and lays eggs. This phenomenon is called as **Neoteny** or **Paedogenesis**.

(5) The reason of retaining larval character and postponement of metamorphosis from aquatic to land animal seems to be due to abundance of food material and other favourable conditions.

(6) The **metamorphosis** to adult becomes difficult as the larva grows older.

(7) The *axolotl larva* in captivity metamorphoses in adult.

(8) It has also been seen that metamorphosis can be induced by injecting thyroid injections into axolotl larva.

(9) Axolotls of six months or more are easily induced for metamorphosis. The partly metamorphosed terrestrial animals can be again induced to go back to larval stage.

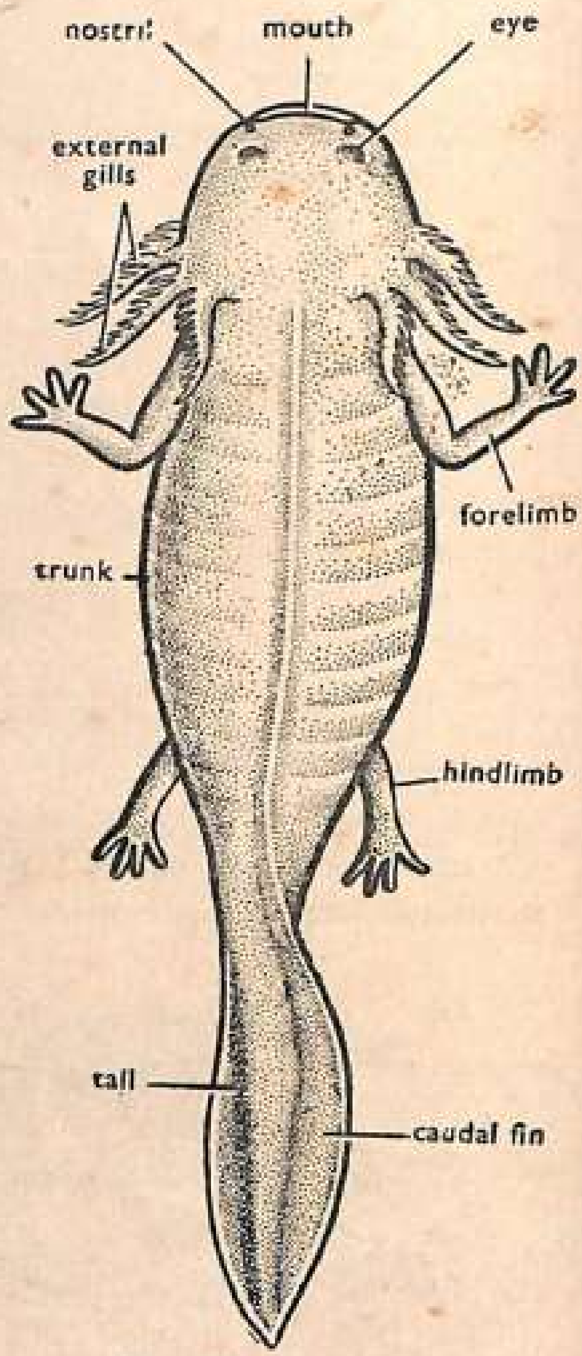


Fig. 3-64. *Axolotl larva.*

Special feature—The phenomenon of **neoteny** or **paedogenesis** is either due to lack of iodine or hereditary and environment. *A. maxicanus* is supposed to be **genetically neotenic.**

63. *Salamandra*

Classification :

Phylum............Chordata	}	Characters same as those of *Ambystoma*.
Subphylum........Vertebrata		
Superclass........Gnathostomata		
Class...............Amphibia		
Order...............Urodela		
Suborder..........Salamandroidea	→	Teeth in roof of mouth behind nares, lungs present, gills absent, eyelids present.
Family.............Salamandridae		
Type................*Salamandra*.		

Geographical distribution—*Salamandra* is distributed in Europe, Eastern Asia and North America. **Eocene** to **Recent**.

Habit and habitat—Terrestrial *Salamandra* commonly inhabits under **logs, stones**, cracks and crevices of the old walls.

Comments :

(1) *Salamandra* is commonly known as **fire salamandra**.

(2) **Body is lizard like,** males measuring 12–15 cms. in length and female is longer than male.

(3) The body is brilliantly black coloured with irregular patches of yellow on the back and limbs.

(4) **Forelimbs** and **hind limbs** well developed. They clearly stand out from the trunk and lift the body well above the ground.

(5) **Head** contains prominent eyes and nostrils.

(6) Tooth-bearing extensions of **prevomers** along **parasphenoids** present.

(7) **Lungs** present. **Gills** and **gill clefts** are absent in adults.

(8) **Vertebrae opisthocoelus.** (9) **Inter-auricular** septum perforated.

(10) **Eyes** are provided with movable **eyelids.** The large **paratoid glands** are present behind the head.

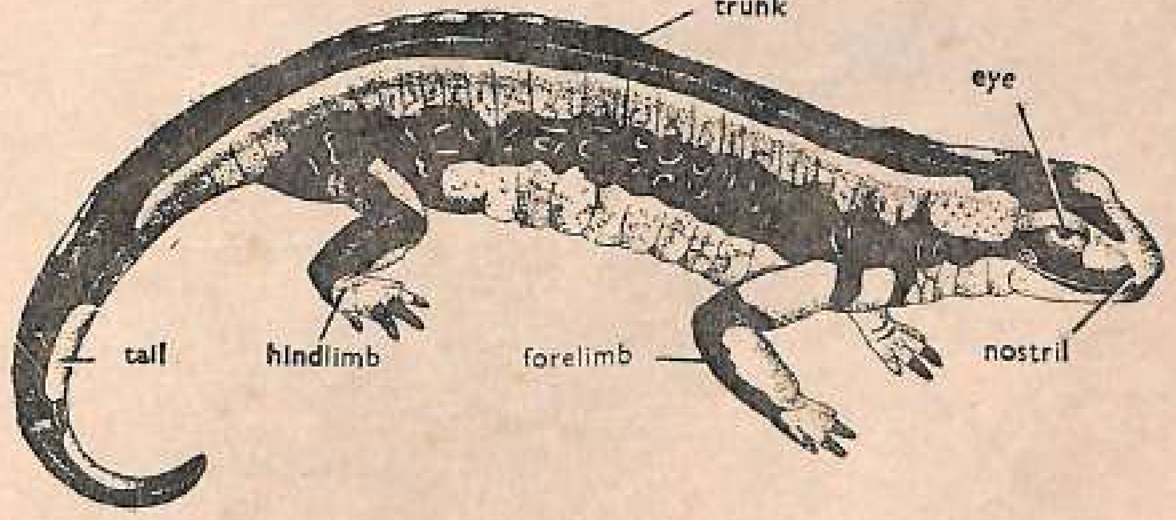


Fig. 3-65. *Salamandra*.

Special feature—Tail is without tail fin. Body is spotted all over. Some forms like *S. maculosa* are viviparous. The eggs develop in oviducts. Larvae have gills which are shed before hatching.

Identification—*By spotted body.*

64. *Triturus*

Classification :

Phylum..............Chordata
Subphylum.........Vertebrata
Superclass..........Gnathostomata
Class.................Amphibia
Order................Urodela
Family..............Salamandridae
Type..................*Triturus.*

(Phylum to Order:) Characters same as those of *Ambystoma.*

Geographical distribution—*Triturus* is distributed in **U.S.A.** from **California** to southern Alaska, and Europe. **Eocene to Recent.**

Habit and habitat—*Triturus* is terrestrial.

Comments :

(1) *Triturus cristatus* is commonly called as **European Crested Newt.**
(2) **Body** is elongated and cylindrical.
(3) Male develops a crest and becomes brilliantly coloured in **breeding season.**
(4) **Head** is conical and compressed, containing wide **mouth** and small **nostrils.**
(5) **Tail** is elongated, thick and provided with **dorsal** and **ventral fins** without **fins rays.**
(6) It is modern tailed Amphibia. (7) **Girdles** and **sternum** are primitive.
(8) **Gills** are absent; **respiration** by skin and lungs.
(9) The larval stage is provided with three pairs of gills, which are lost in adults.

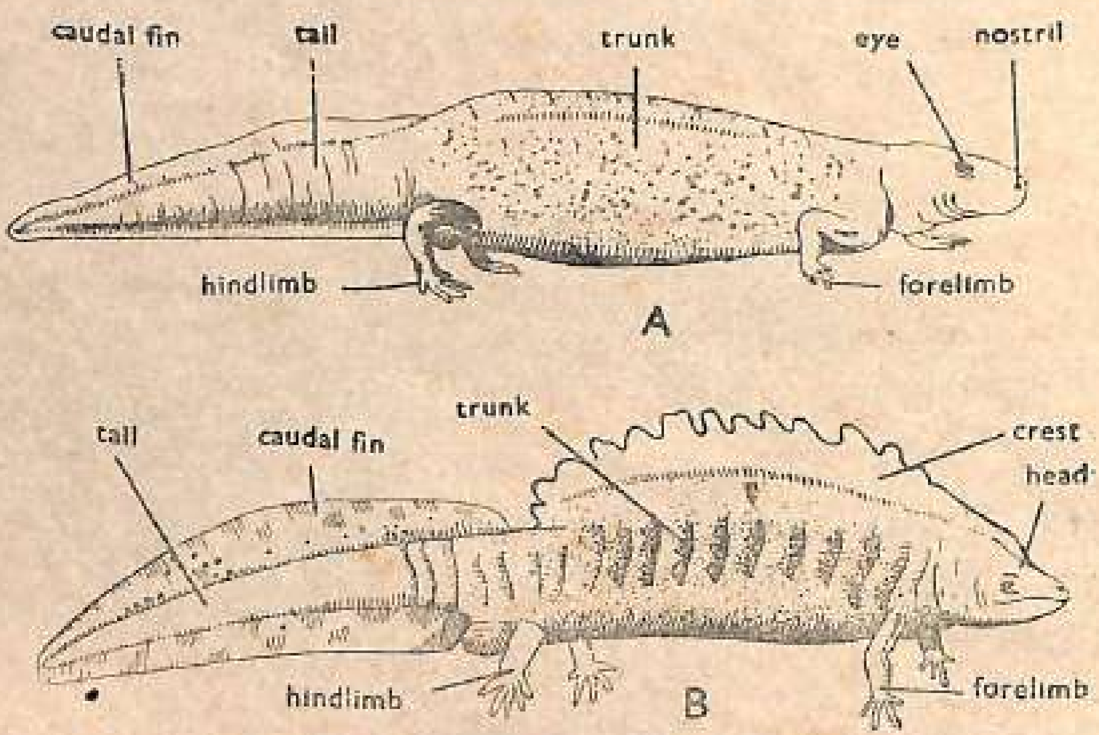


Fig. 3-66. *Triturus.* A—Female. B—Male.

(10) **Vertebrae opisthocoelus.**

Identification—*By thick tail and crest in male.*

65. Amphiuma

Classification :

Phylum............Chordata
Subphylum.......Vertebrata
Superclass.......Gnathostomata
Class..............Amphibia
Order..............Urodela
} Characters same as those of *Ambystoma.*

Suborder..........Amphiumoidea → Body cylindrical, eyelids absent, adults contain gills, lungs and gill slits and small limbs with 2 or 3 toes.

Family............Amphiumidae
Type...............*Amphiuma.*

Geographical distribution—*Amphiuma* is distributed in Missouri and Virginia (United States). **Eocene to Recent.**

Habit and habitat—*Amphiuma* is commonly found in **swampy meadows** and in rice fields. It feeds on molluscs, crayfishes and small fishes.

Comments :

(1) *Amphiuma* is commonly known as **Congo eel.**

(2) **Body** is covered with smooth and black skin and animal measures about 90 cms. in length.

(3) **Eyes** are well developed and functional, but without eyelids.

(4) **Limbs** are poorly developed, rudimentary and do not help in locomotion. Toes 2 or 3.

(5) Gill clefts are two in number. (6) **Lungs** are present. **Trachea** is long.

(7) Eggs are laid in water and female coils around the eggs till they hatch.

Special feature—*Amphiuma* is also a perennial, partly metamorphosed salamandrid derivation with small eyes. *Amphiuma* has largest erythrocytes, measuring 80 microns.

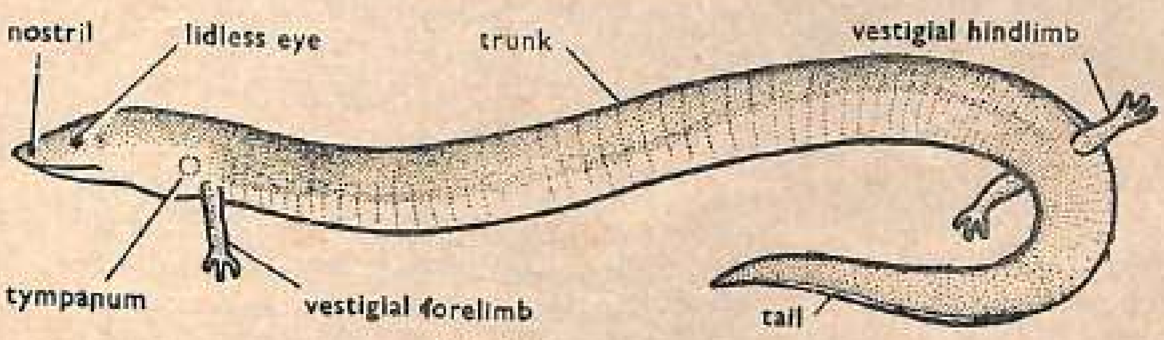


Fig. 3-67. *Amphiuma.*

66. Siren

Classification :

Phylum..............**Chordata**		
Subphylum..........**Vertebrata**		
Superclass..........**Gnathostomata**		Characters same as those of *Ambystoma*.
Class...................**Amphibia**		
Order..................**Urodela**		
Suborder............**Meantes**	→	Body slender, hind limbs and eyelids absent, gills persistent, jaws with horny covering and permanently aquatic.
Family...............**Sirenidae**		
Type..................*Siren.*		

Geographical distribution—*Siren* is found in the United States, chiefly in Virginia, Indiana, Florida and Texas. **Pleistocene to Recent.**

Habit and habitat—*Siren lacortina* is found in the burrows, muddy ditches and ponds.

Comments :

(1) *Siren* is commonly known as **mud eel.**

(2) Body of the animal is slender, elongated and measuring 75 cm. in length.

(3) Head is conical with small eyes and nostrils. (4) **Jaws** with horny covering.

(5) There are 3 pairs of **external gills** which are persistent. Gills slits one pair.

(6) **Eyes** are without eyelids.

(7) **Forelimbs** are small containing **4 digits**, while **hind limbs** are absent.

(8) **Tail** is provided with small **caudal fin.** (9) Body is covered with small papillae.

(10) Cloacal glands are absent. **Fertilization** is probably external.

Special feature—*Siren* is also a permanent larval form with only a few adult features.

Identification—*By slender body, gills and only forelimbs.*

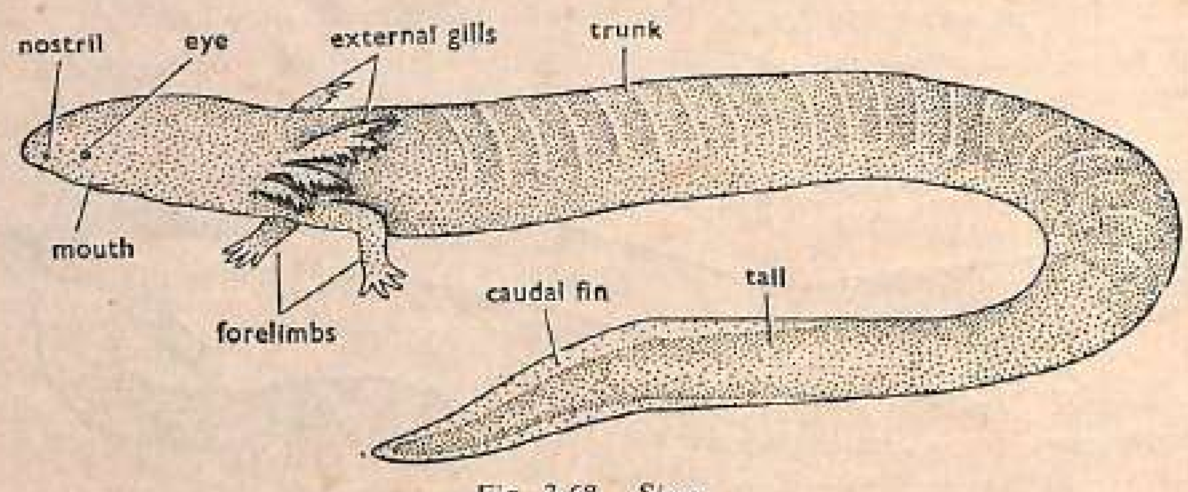


Fig. 3-68. *Sireu.*

67. *Bombinator*

Classification :

Phylum..................	**Chordata**	→ Dorsal tubulated nerve cord, notochord and gill slits present.
Subphylum............	**Vertebrata**	→ Internal skeleton of cartilage or bone, spinal cord forming main axis and composed of overlapping vertebrae. Nervous system dorsal to alimentation, complex brain, red blood and two pairs of appendages.
Superclass............	**Gnathostomata**	→ Jaws and paired appendages present.
Class....................	**Amphibia**	→ Cold blooded, scaleless glandular skin, can live in water and land, two occipital condyles, heart three-chambered and none marine.
Order....................	**Anura** or **Salientia**	→ Scaleless Amphibia. Tail, external gills and gill slits absent. Both hind limbs and forelimbs well developed.
Suborder................	**Opisthocoela**	→ Vertebrae opisthocoelus, ribs free.
Family..................	**Discoglossidae**	
Type.....................	***Bombinator***.	

Geographical distribution—*Bombinator* is found in Europe, Eurasia and China. **Miocene.**

Habit and habitat—*Bombinator* lives in standing water with hygrophytic vegetation.

Comments :

(1) *Bombinator* is commonly known as **fire-bellied toad.**

(2) The body of the animal measures about 5 cms.

(3) The **dorsal** surface is black or grey, while ventral surface is bluish black with irregular red or orange patches looking like fire.

(4) **Tympanic membranes** and **vocal sacs** are absent.

(5) **Eustachian** tube is small.

(6) **Vertebrae opisthocoelus.**

(7) **Tongue** and **eyelids** present.

(8) Adults have **ribs.**

(9) **Forelimbs** and hind limbs are well developed. Hind limbs are enlarged for **leaping.** **Webbed toes.**

(10) Egg deposition and fertilization external by "clasped" male and female. Larva is **tadpole.**

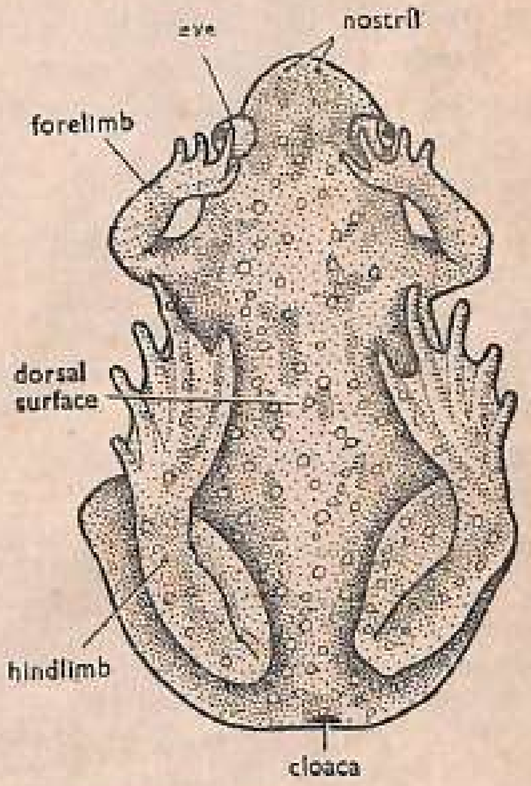


Fig. 3-69. *Bombinator*.

Special feature—*Bombinator ignem* is common fire-bellied toad. The abdomen and entire ventral surface is brilliantly coloured with **bluish-black** and irregular red or **orange patches.** Dorsal surface grey or **olive-black.** When disturbed, it exposes its belly against the enemies. The shaking water gives a flame-like appearance and hence called as **fire-bellied toad.** When the toad is disturbed on land, head is thrown back, limbs turned upwards, belly is exposed with coloured patches and teeth produce **hissing** sound.

Identification—*By coloured patches on abdomen.*

68. *Alytes*

Classification :

Phylum............**Chordata**		
Subphylum.........**Vertebrata**		
Superclass.........**Gnathostomata**		
Class...............**Amphibia**	}	Characters same as those of *Bombinator*.
Order...............**Anura**		
Suborder..........**Opisthocoela**		
Family.............**Discoglossidae**		
Type................*Alytes*.		

Geographical distribution — *Alytes* is found in European countries. **Miocene.**

Habit and habitat—*Alytes* is an amphibious toad.

Comments :

(1) *Alytes* is commonly known as **Midwife toad.**

(2) **Body** of the animal has **warty surface, grey, brown, green** or red **coloured** and is measuring 5–8 cms. in length.

(3) Upper **jaw** toothed, and transverse process of **sacral** vertebrae dilated.

(4) **Vertebrae opisthocoelus.**

(5) **Tongue** is in the form of rounded non-protrusible disc.

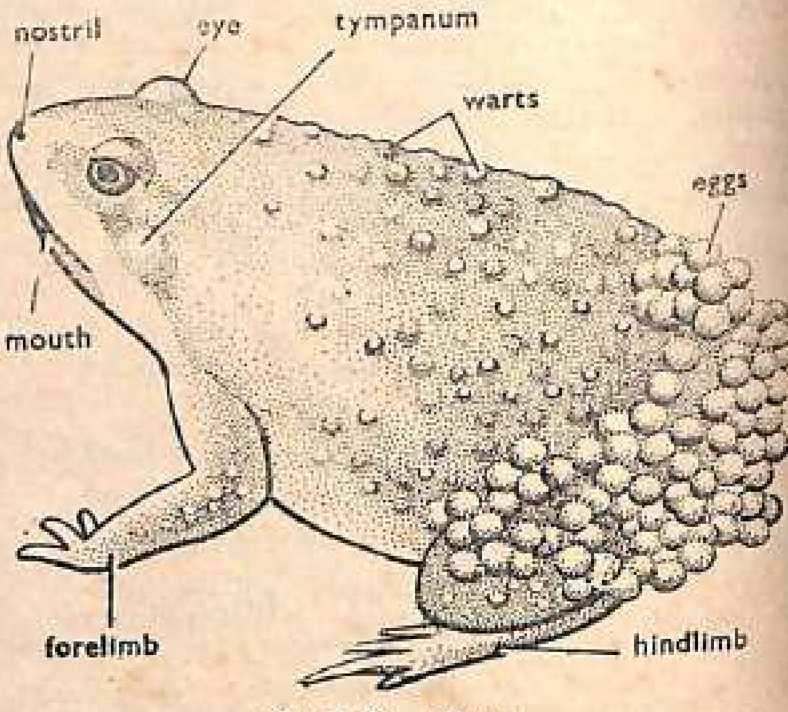


Fig. 3-70. *Alytes.*

(6) **Males** are without vocal sacs.

(7) **Larva** contains median spiracle.

(8) **Tympanum** is large.

(9) Eyelids are present. **Adults have ribs.**

(10) Fertilization and egg deposition external.

Special feature—The midwife toad has peculiar **breeding habit**. The male toad massages the cloaca of female with the strokes of its toes. The **female** lays eggs **in strings** and the male toad **winds** the strings containing eggs around posterior body and thighs and it goes in moist earth. Occasionally, the male toad comes in water for dip to moist the eggs. When eggs develop to tadpole stage and ready for hatching, the toad comes in water and larvae hatch. This shows **parental care.**

69. *Pipa*

Classification :

Phylum............**Chordata**		
Subphylum........**Vertebrata**		
Superclass........**Gnathostomata**		
Class...............**Amphibia**	}	Characters same as those of *Bombinator*.
Order...............**Anura**		
Suborder..........**Opisthocoela**		
Family.............**Pipidae**		
Type................*Pipa*.		

Geographical distribution—*Pipa* is commonly found in northern South America. **Miocene.**

Habit and habitat—*Pipa* is strictly aquatic.

Comments :

(1) *Pipa* is commonly known as **Surinum toad.**

(2) Body of the animal has **shabby looks** with a triangular and depressed head. Eyes are small.

(3) Upper part of snout is produced into irregular flaps and tentacles.

(4) **Tongue** and **eyelids** are absent.

(5) **Dermal papillae** are present.

(6) **Jaws do** not contain teeth, but have **horny** substitute.

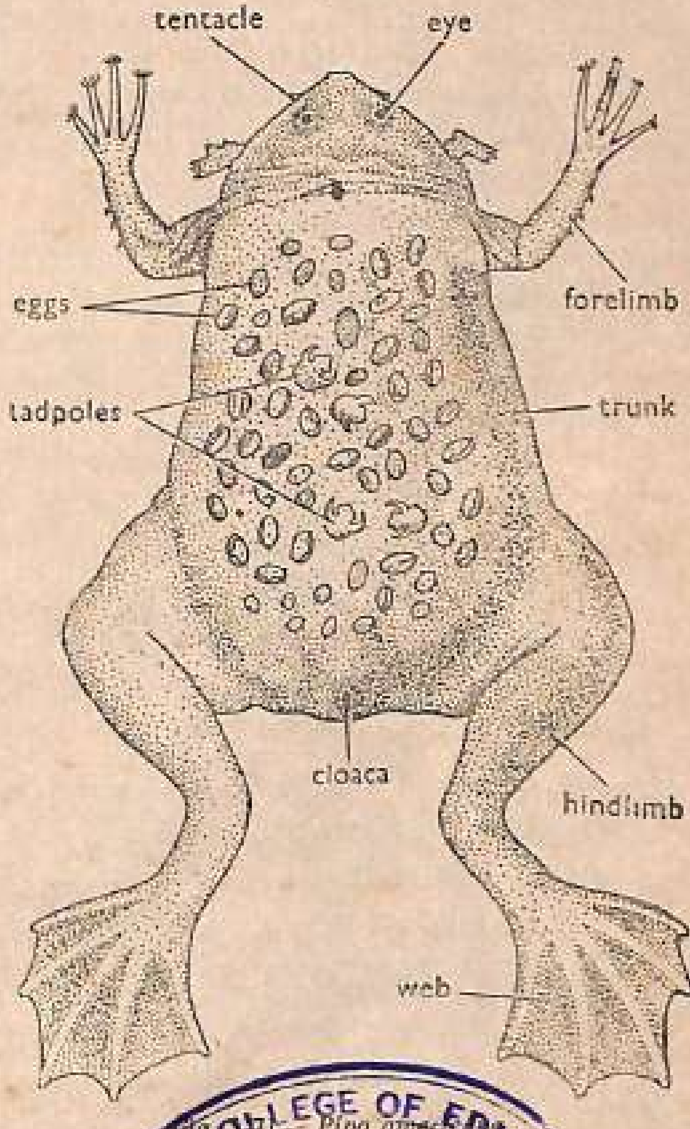
(7) **Eustachian tube** opens into the **pharynx.**

(8) **Forelimbs** are small and papillae star-shaped, having sensory processes while hind limbs are fully **webbed.**

(9) The **skin** contains **poison** glands.

(10) **Vertebrae opisthocoelus.**

Special feature—The **breeding habit** is peculiar. Female toad shows parental care. During breeding season, the skin of female becomes soft. The male clasps the female and presses the female and eggs come out. The male also releases sperms which fertilize eggs. The fertilized eggs attach to the back of the female. Each egg is enclosed in a **vascular pouch** covered with operculum. The embryo develops yolk sac and vascular tail for exchange of **metabolites.** Gills are not formed and fully-developed young ones come out from the pouch. The female changes its back skin after embryos escape.



— *Pipa ameri*

70. Bufo

Classification :

Phylum ....**Chordata**		
Subphylum........**Vertebrata**		
Superclass ....**Gnathostomata**	}	Characters same as those of *Pipa.*
Class...............**Amphibia**		
Order...............**Anura**		
Suborder..........**Procoela**	→	Vertebrae procoelus and urostyle with double condyle.
Family.............**Bufonidae**	→	True toads.
Type................*Bufo.*		

Geographical distribution—*Bufo* has world-wide distribution. They are abundantly found in India, United States and the Pacific state of Alaska. **Miocene.**

Habit and habitat—*Bufo* is **terrestrial, nocturnal,** hiding under logs and stones or it burrows in day. It enters water only to breed and spawn.

Comments :

(1) *Bufo* is commonly called as **true toad.**

(2) *Bufo* differs from frog in having **rough, dry** and **warty skin** with more **poison glands** than mucous glands.

(3) Behind eyes there is a pair of large **paratoid poison** glands. The skin is more or less of protective nature than respiratory.

(4) Eyes are large. Hind limbs are short and provided with horny tips.

(5) **Webs** are poorly developed.

(6) **Maxilliary teeth,** sternum absent and ventral parts of **pectoral girdle** overlap (**arciferous**). **Sacral vertebra** has dilated transverse processes.

(7) **Liver** is bilobed.

(8) **Glands** of sirammerdans absent. **Vertebrae procoelus.** Urostyle with double condyle.

(9) Eggs are pigmented and laid in gelatinous string.

(10) Young toads mature in many years.

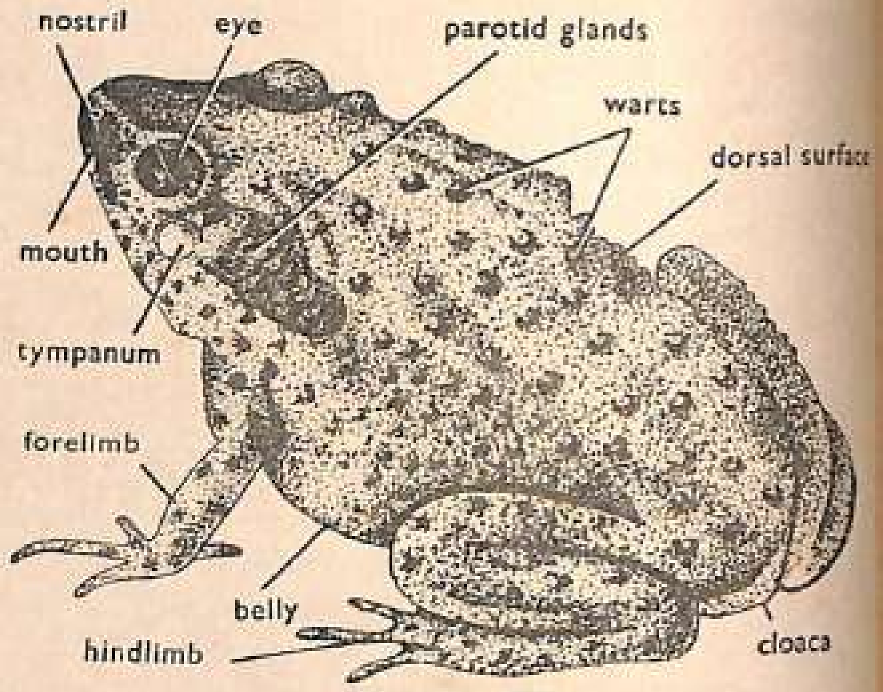


Fig. 3-72. *Bufo.*

Special feature—The paratoid glands of the toad secrete two toxic substances **bufotalus** and **bufogus.** These toxins cause nausea, respiratory and muscular disturbances and also effect heart functioning, if swallowed by man. *Bufo molanostictus* is found upto 3000 meters in the Himalayas.

71. *Hyla*

Classification :

Phylum............**Chordata**		
Subphylum........**Vertebrata**		
Superclass........**Gnathostomata**		
Class...............**Amphibia**	}	Characters same as those of *Bufo.*
Order...............**Anura**		
Suborder..........**Procoela**		
Family.............**Hylidae**	→	Tree toads.
Type................*Hyla arborea.*		

Geographical distribution—*Hyla* is commonly distributed in India, China, United States, Africa and Canada. **Miocene.**

Habit and habitat—*Hyla* is arboreal in habit, living on trees and rocks.

Comments :

(1) *Hyla arborea* is commonly known as **tree frogs.**

(2) Body of the animal is adapted for arboreal life and is measuring 3–8 cms. in size.

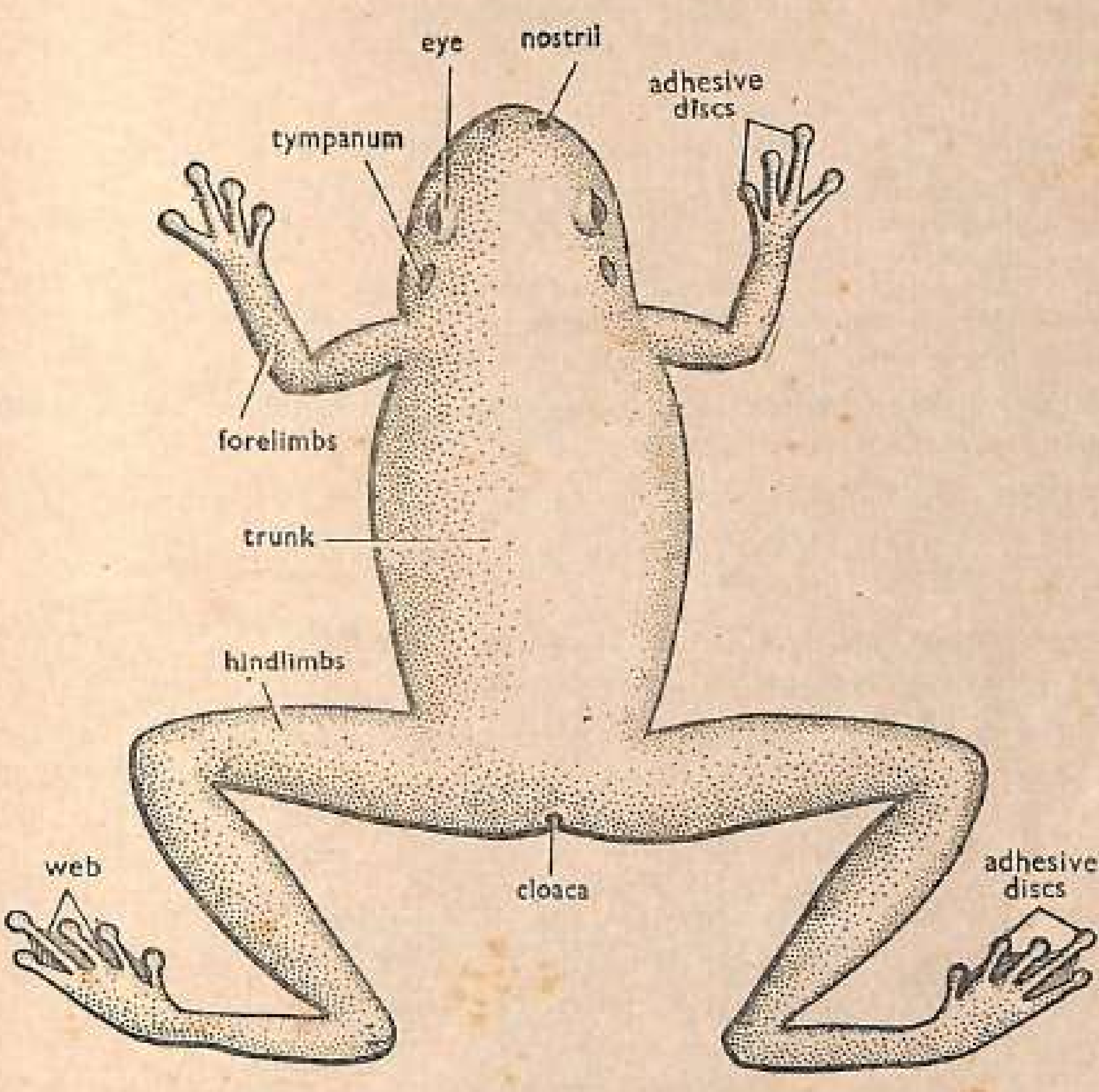


Fig. 3-73. *Hyla.*

(3) Terminal bone of each digit is claw **shaped** and all toes contain expanded **adhesive cushions,** which are used to **climb** trees or rocks.

(4) **Upper jaw** is toothed and transverse processes of sacral vertebra are dilated.

(5) **The lower jaw** is without teeth **(edentulous).**

(6) Eyes well developed with horizontal pupil. (7) **Tympanum** is distinct.

(8) **The skin** on belly contains hygroscopic glands which help in adhering the frog with leaf, twigs or stem.

(9) **Voice** often loud. (10) **Fertilization** external. Eggs are laid in water.

(11) Development includes tadpole larva.

Special feature— *Hyla arborea, Hyla versicolour* and *Hyla regita* etc., are all tree-living frogs, are adapted from **amphibious** to **arboreal** life. They also **change** their **colour** according to their environment and show **camouflage** or **mimicry.**

Identification—*By adhesive disks in limb toes.*

72. Rhacophorus

Classification :

Phylum............**Chordata**		
Subphylum........**Vertebrata**		
Superclass.........**Gnathostomata**	}	Characters same as those of *Hyla*.
Class...............**Amphibia**		
Order...............**Anura**		
Suborder.........**Diplasiocoela**	→	Pectoral girdle fused to sternum.
Family.............**Polypedatidae**	→	Old World tree frogs.
Type...............*Rhacophorus*.		

Geographical distribution—The tree frogs or flying frogs are found in Africa, South-eastern Asia, Japan and Madagascar. **Miocene.**

Habit and habitat—*Rhacophorus* is a tree-living frog. It remains calm and quiet under stones or on trees and comes out during **twilight.**

Comments :

(1) *Rhacophorus* is commonly known as **flying frog** or **tree frog.**

(2) **Head** is broad and somewhat conical in shape.

(3) Eyes with eyelids well developed.

(4) **Tympanum** behind the eyes.

(5) The **belly** narrows posteriorly.

(6) **Body** is slender and **limbs** are elongated.

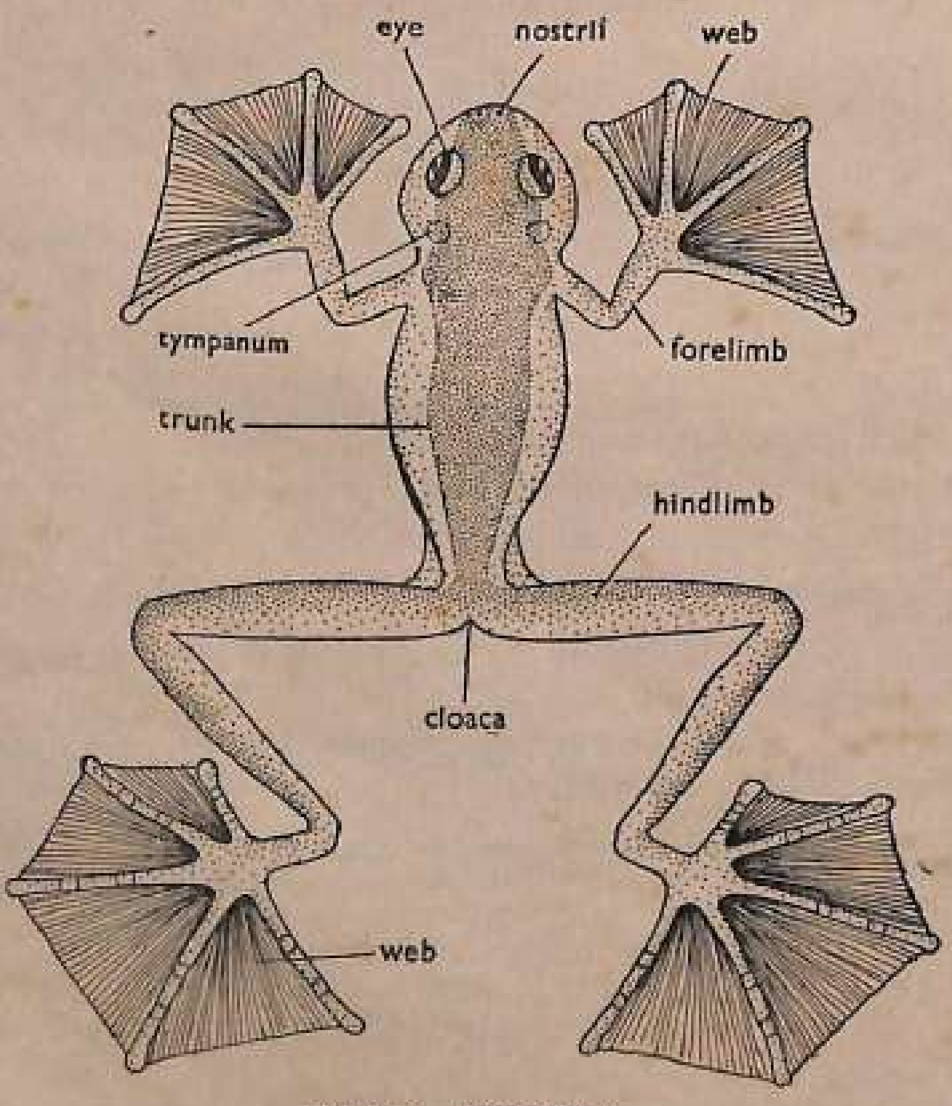


Fig. 3-74. *Rhacophorus.*

(7) The **forelimb** contains well-developed **webs in digits.** The **digits** also bear **adhesive cushions** at tips. The **digits** of **hind limbs** also contain **web.** The digits also contain **intercalary cartilages.**

(8) The flying frogs climb on trees and walls and occasionally glide and while alighting on ground, the webs are spread like parachute.

(9) Eggs are laid usually in gelatinous foam over water, placed in the shallow water of pools and rice fields.

(10) Females are larger than males.

(11) *Rhacophorus* has power of rapid **colour changing.**

Special feature—*Rhacophorus* shows extreme degree of adaptive radiation in frogs as it has acquired the power of flying or parachuting while alighting from trees.

G. MUSEUM SPECIMENS OF REPTILES

NATURAL HISTORY

Class Reptilia includes lizards and snakes (order **Squamata**), the turtles and tortoises (order **Chelonia**), crocodiles and Alligater (order Crocodilia) and tuatara (order Rhynchocephalia). These represent only 4 of the 16 orders that lived and flourished in Mesozoic era. Reptiles are first vertebrates adapted for life on dry land. The class name refers to the mode of travel (Latin *reptum*=to creep). Reptiles show advance over the amphibians in having (1) **dry** scaly body covering, adapted to life away from water, (2) **limbs** suited for rapid **locomotion,** (3) further **separation** of oxygenated and non-oxygenated blood in the heart, (4) **complete** ossification of skeleton, and (5) eggs suited for development on land with membranes.

Most reptiles live in tropical and subtropical regions, their number declining towards poles. Turtles and snakes are abundant in humid regions. Reptiles have radiated towards all kinds of habitat *i.e.* land, water and air. In winter they lead dormant life, hibernate in crevices. Snakes are injurious to mankind and still man fears them very much. Many kinds of snakes and lizards benefit man by providing food, by destroying harmful rodents and insects. Skin of snakes and crocodiles is of great economic importance.

Outline Classification

Phylum............**Chordata**
Subphylum.......**Vertebrata**
Superclass........**Gnathostomata**
Class...............**Reptilia**

1. *Subclass*..........**Anapsida**
   (*a*) *Order*.......**Cotylosauria**—Stem reptiles, *e.g.* *Seymouria.*
   (*b*) *Order*.......**Chelonia**
      (*i*) *Suborder*...**Atheca,** *e.g.* *Dermochelys.*
      (*ii*) *Suborder*...**Thecophora**
         Family (*1*) **Testudinidae,** *e.g.* *Chrysemys, Terrapene, Testudo, Kachuga.*
         Family (*2*) **Chelonidae,** *e.g.* *Chelone, Caretta.*
         Family (*3*) **Trionychoidae,** *e.g.* *Trionyx.*
2. *Subclass*..........**Parapsida**—All extinct, *e.g.* *Ichthyosaurus* and *Mesosaurus.*
3. *Subclass*..........**Diapsida**
   (*a*) *Order*.......**Rhynchocephalia,** *e.g.* *Sphenodon.*
   (*b*) *Order*.......**Squamata**
      (*i*) *Suborder*...**Sauria** or **Lacertilia**
         Family (*1*) **Geckonidae,** *e.g.* *Hemidactylus, Gecko.*
         Family (*2*) **Iguanidae,** *e.g.* *Anolis, Phrynosoma, Sauromalus, Iguana* and *Crotophytus.*
         Family (*3*) **Agamidae,** *e.g.* *Agama, Draco, Moloch* and *Calotes.*
         Family (*4*) **Scincidae,** *e.g.* *Mabuia.*
         Family (*5*) **Chamaeleontidae,** *e.g.* *Chamaeleon.*

Family (6) **Varanidae**, *e.g. Varanus.*
Family (7) **Helodermidae**, *e.g. Heloderma.*
Family (8) **Anguidae**, *e.g. Ophiosaurus, Rhineura.*

(*ii*) *Suborder*...**Ophidia** (**Serpentes**)—It includes snakes which are grouped in the following families :
Family (1) **Typhlopidae**, *e.g. Typhlops.*
Family (2) **Leptopyphlopidae**, *e.g. Leptotyphlops.*
Family (3) **Anilidae**
Family (4) **Boidae**, *e.g. Python molorus, Eryx johnii.*
Family (5) **Uropeltidae**, *e.g. Uropeltis.*
Family (6) **Colubridae**, *e.g. Ptyas mucosus, Natrix, Dendrophis.*
Family (7) **Dasypeltidae**, *e.g. Elachistodon.*
Family (8) **Hydrophiidae**, *e.g. Hydrophis.*
Family (9) **Elapidae**, *e.g. Crotalus, Bungarus, Naja naja, Naja hannah, Elaps.*
Family (10) **Viperidae**, *e.g. Vipera russeli, Ancistrodon* (**pit viper**).

(*c*) *Order*.......**Crocodilia**, *e.g. Crocodilus, Gavialis* and *Alligator.*
(*d*) *Order*.......**Pseudosauria**—Extinct, *e.g. Saltopseudon.*
(*e*) *Order*.......**Saurischia—Extinct**, *e.g. Tryanosaurus, Brontosaurus* and *Diplodocus.*
(*f*) *Order*.......**Ornithischia**—Extinct, *e.g. Iguanodon* and *Triceratops.*
(*g*) *Order*.......**Pterosauria**—Extinct, *Pteranodon* and *Rhamphorhynchus.*

4. *Subclass*..........**Synapsida**—Mammal-like reptiles, *e.g. Varanosaurus* and *Dimetrodon.*

73. Testudo

Classification :

Phylum..................**Chordata**	→	Dorsal tubulated nerve cord, notochord and gill slits present.
Subphylum.............**Vertebrata**	→	Internal skeleton of cartilage or bone, spinal cord forming main axis and composed of overlapping vertebrae, nervous system dorsal to alimentation, complex brain, red blood and two pairs of appendages.
Superclass..............**Gnathostomata**	→	Jaws and paired appendages present.
Class.......................**Reptilia**	→	Scaly vertebrates with light and left aortic arches, single condyle, pulmonary respiration and embryo with amnion and allantois.
Subclass.................**Anapsida**	→	Primitive reptiles, skull completely roofed over.
Order.......................**Chelonia**	→	Turtles, tortoises and terrapins.
Suborder................**Thecophora**	→	Thoracic vertebrae and ribs fused to carapace.
Family....................**Testudinidae**		
Type.......................*Testudo.*		

Geographical distribution—*Testudo* is widely distributed in Galapago Islands, Africa, Europe, India and Sri Lanka. **Jurassic to Recent.**

Habit and habitat—*Testudo* is found in fresh water or salt water or on land. It **feeds** on small worms and insects. It also **hibernates** during winter season.

Comments :

(1) *Testudo* is commonly known as **giant land tortoise.**

(2) Body of the animal is encased in a **rigid shell** of dorsal **carapace** and ventral **plastron** which are joined at sides.

(3) The **carapace** is convex, devoid of nuchal plate and containing polygonal **scales.**

(4) **Plastron** is concave. (5) Carapace is covered with polygonal scutes or **leathery skin.**

(6) The neck is band like and can be withdrawn into shell.

(7) **Teeth absent. Jaws** with horny sheaths. **Quadrate** immovable.

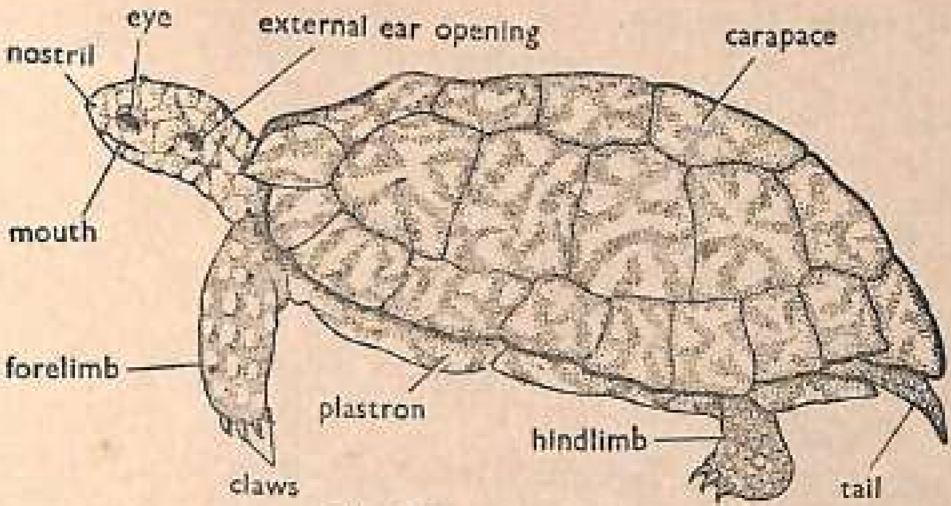


Fig. 3-75. *Testudo*.

(8) **Thoracic vertebrae** and ribs usually fused to carapace.

(9) Anal slit lengthwise. Copulatory organ single.

(10) Skull roof solid, no opening behind eyes. **Stumpy tail present.**

Special feature—The feet are adapted for walking on land. The clawed digits contain only two phalanges. **Oviparous.** Eggs are laid in holes (nests) in ground, dug and covered by females. Toes not webbed.

Identification—*By polygonal scales.*

74. Chrysemys

Classification : Same as those of *Testudo*.

Geographical distribution—*Chrysemys* is commonly found in India, Sri Lanka, U.S.A., Galapago Islands, Europe, Asia and Africa, except Australian region. **Eocene to Recent.**

Habit and habitat—*Chrysemys* is a common freshwater form, but is adapted for amphibious life. It feeds on insects, worms and other animals.

Comments :

(1) *Chrysemys* is commonly called as **painted terrapin.**

(2) **Body** is **encased** in a **bony armour** of dorsal **carapace** and ventral **plastron.** The nuchal shield is elongated and narrow. **Keel absent.**

(3) **Plastron** is provided with transverse hinge.

(4) The **costal** and **neural** plates of the carapace are convex and dome-shaped.

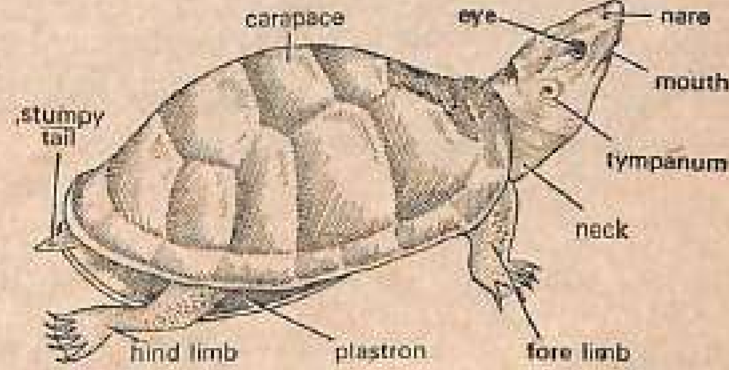


Fig. 3-76. *Chrysemys*.

(5) **Marginal** plates communicate with the plastron.

(6) **Head** is triangular containing **eye, mouth, nares** and **tympanum.**

(7) There is a fold of skin behind the head.

(8) Forelimb and backwardly directed hind limbs well developed. Middle front toe with **3 phalanges.** Toes partly **webbed.**

(9) **Temporal vacuities** are absent.

(10) **Neck** is retractile. **Neck, limbs** and **tail** contain beautiful and brilliant coloured stripes.

Identification—*By webbed toes.*

75. *Kachuga tectum*

Classification : Same as those of *Testudo.*

Geographical distribution—*Kachuga* is distributed in Indian rivers, specially Ganges. **Eocene** to **Recent.**

Habit and habitat—*Kachuga* is commonly found in rivers. They concentrate especially at bathing places and also at places where dead bodies are disposed in water. Their food consists of both plants and animals.

Comments :

(1) *Kachuga* is commonly called as **tortoise.**

(2) It is an **armoured reptile** showing gradation between terrestrial and aquatic extremes.

(3) Body is encased in **carapace-plastron** box.

(4) Outer surface consists of leathery skin.

(5) The first three **neural plates** of the carapace are produced into **backwardly** directed **spines.**

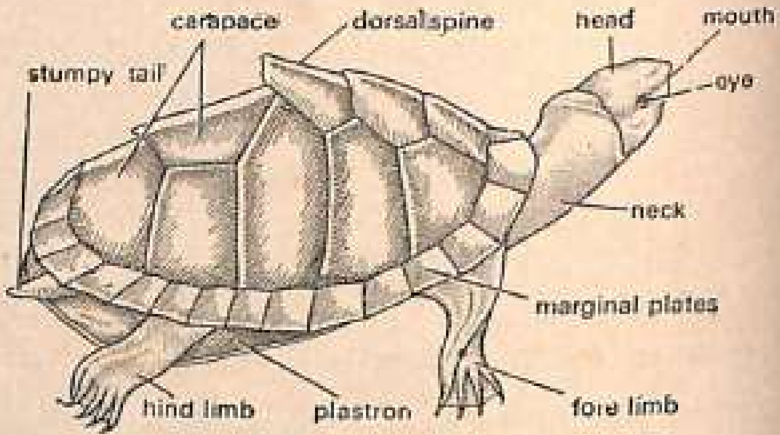


Fig. 3-77. *Kachuga.*

(6) **Head** is retractile into the carapace.

(7) **Head** contains several **crests** and is **brightly coloured.**

(8) **Tail** is stumpy.

(9) Limbs terminate into clawed and webbed digits.

(10) Eyes are provided with **eyelids** and **nictitating membrane.**

Identification—*By dorsal spine.*

76. *Chelone*

Classification:

Phylum............**Chordata**
Subphylum.......**Vertebrata**
Superclass.......**Gnathostomata**
Class..............**Reptilia**
Subclass..........**Anapsida**
Order..............**Chelonia**
Suborder..........**Thecophora**

} Characters same as those of *Testudo.*

Family............**Chelonidae**
Type...............*Chelone.*

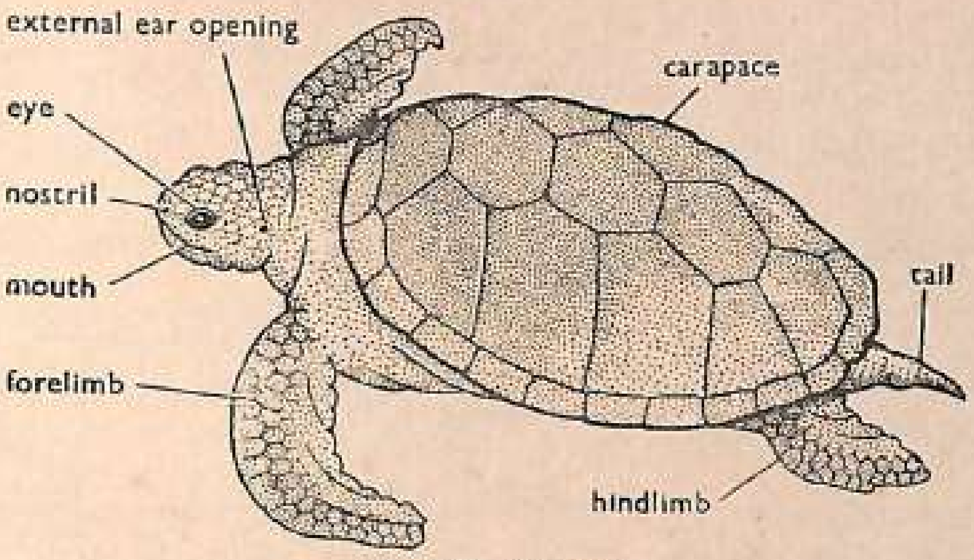


Fig. 3-78. *Chelone.*

Geographical distribution—*Chelone* is distributed in tropical and subtropical regions and chiefly found in the Indian, Pacific and Atlantic oceans and coasts of the United States. **Cretaceous** to **Recent.**

Habit and habitat—*Chelone mydas* is a **marine** reptile. They come ashore only to lay eggs.

Comments :

(1) *Chelone mydas* is commonly called as **green turtle.**
(2) It measures about 110 cms.
(3) **Body** case is rigid. The **carapace** is flat, heart-shaped and covered with smooth **bony shields.**
(4) **Plastron** is joined to carapace by ligament and **osteoderms** of plastron have large unossified space in the middle.
(5) The dorsal shields are juxtaposed fitting closely into each other. Costal shields 4 pairs.
(6) The head is covered by single pair of prefrontal shields.
(7) Eyes well developed, provided with **eyelids** and **nictitating** membrane.
(8) **Limbs flipper** like. The forelimbs form wing-like **paddles.** Only first digit is clawed while hind limbs clawed.
(9) Jaws contain denticulate edges. (10) Head is partially retractile into shell.

Special feature—The sea **turtles** are **economically** important; because their armour is utilized for various purposes and their flesh is edible, being very delicious. *Chelone* weighs about 200 lbs. and is much valued for food.

Identification—*By flipper-like limbs.*

77. *Trionyx*

Classification :

Phylum..............**Chordata**		
Subphylum.........**Vertebrata**		
Superclass.........**Gnathostomata**		
Class.................**Reptilia**	Characters same as those of *Chelone.*	
Subclass............**Anapsida**		
Order................**Chelonia**		
Suborder............**Thecophora**		
Family...............**Trionychoidae**		
Type..................*Trionyx.*		

Geographical distribution—*Trionyx* is widely distributed in India, North America, Africa, Asia and Malaya Archipelago. **Cretaceous to Recent.**

Habit and habitat—*Trionyx gangeticum* is a common freshwater and pond **terrapin.**

Comments :

(1) *Trionyx* is commonly called as **tortoise** or **soft river terrapin.**

(2) **Body** is flat, oval and encased in bony shell. The skin is smooth and leathery.

(3) Dorsal surface is olive above and yellowish below.

(4) The **carapace** is fused with vertebral column and ribs.

(5) Carapace consists of 9 **median vertebral** plates corresponding to trunk vertebrae and fused with the flattened **neural spines** of corresponding vertebrae. To these a median **nuchal and 2 precaudals** are added.

(6) **Lateral** parts of carapace is composed of **8 costal plates.** Marginal plates are added to costal and precaudals.

(7) **Plastron** best seen in inner surface consists of a pair of **epiplastron,** a median entoplastron and paired **hyo, hypo** and **xiphiplastron.**

(8) Only neck and tail vertebrae are movable.

(9) Feet are broadly webbed and only three inner digits are clawed.

(10) Head is pointed with greenish or blackish longitudinal streaks. Lips are fleshy. Horny beak is absent.

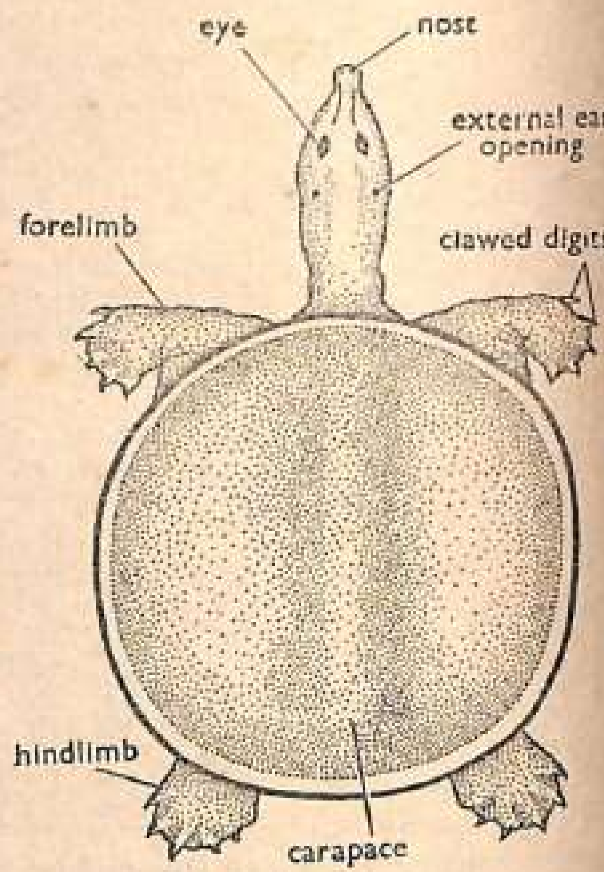


Fig. 3-79. *Trionyx.*

Special feature—**Oviparous.** **Eggs** are laid outside water. **Because of rigid shell** the breathing movements are produced by protrusion of the head, movements of girdles, limbs and pumping action of **hyoid.**

Identification—*By clawed digits, webbed feet and longitudinal streaks over head.*

78. *Sphenodon*

Classification :

Phylum................**Chordata**		Characters same as those of *Trionyx*.
Subphylum.........**Vertebrata**		
Superclass...........**Gnathostomata**		
Class.....................**Reptilia**		
Subclass..............**Diapsida**	→	Reptiles without temporal openings separated by the post-orbito-squamosal arch.
Order...................**Rhynchocephalia**	→	Living fossil, lizard-like, ribs single headed and with uncinate process and vertebrae amphicentrous.
Type.....................*Sphenodon punctatum*.		

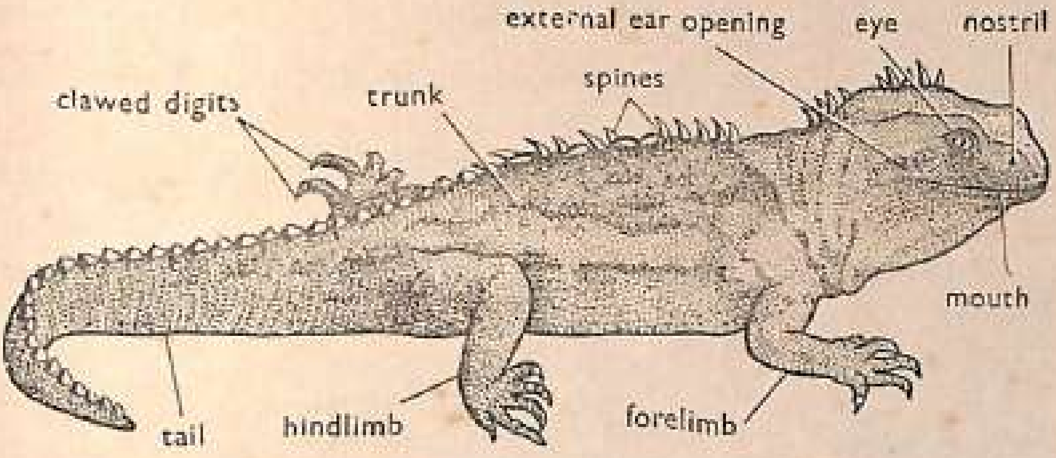


Fig. 3-80. *Sphenodon.*

Geographical distribution—*Sphenodon* is found in New Zealand and specially in the islets of Bay of Plenty. **Permian** to **Eocene** and **Recent.**

Habit and habitat—*Sphenodon* lives in burrows, leads semiaquatic life. It is nocturnal and eats insects, molluscs or small invertebrates. It also produces frog-like croak.

Comments :

(1) *Sphenodon punctatus* is commonly called as **Tuatara.**

(2) Body is lizard-like having dull olive-green colour with white and yellow spots and measuring about 75 cms.

(3) Animal contains **scaly skin, long tail** and four **pentadactyl limbs** adapted for walking. Several **crest-like**, spiny scales extend along mid-dorsal line.

(4) The skull contains two complete **fossae, quadrate** is fixed, **postfrontals** are separate (only in *Sphenodon*) and upper jaw has **beaks.**

(5) Mandibles joined by ligament.

(6) **Teeth acrodont, sternum** present and **vertebrae amphicoelus.**

(7) Between **skull** and atlas is **proatlas.** (8) **Caudal** vertebrae have **chevron bones.**

(9) There is prominent **parietal eye** with retina, lens and nervous connection to brain. It is **photosensitive.**

(10) Viscera like lizard. Abdominal ribs present.

(11) *Sphenodon* possesses several primitive features such as two temporal fossae, amphicoelus vertebrae, rib-like ossification in abdomen, uncinate process in ribs and beak in upper jaw.

(12) Anal opening transverse. **Male without** copulatory organ. About 10 **eggs** with hard white shell are laid in holes in the ground. Eggs require 13 months to hatch. Breeding season is November to February.

Special feature—*Sphenodon punctatus* is the important **living fossil.** It has survived from **Permian** and is fast approaching towards extinction. **It is protected by law.** The **tuatara** contains several **primitive features,** such as two **temporal** fossae, **amphicentrous** vertebrae, **pineal** eye, **uncinate** processes in the rib, **vomerine** teeth in young, **horny** back on upper jaw and absence of copulatory apparatus in males. **Tuatara** is close to the type from where all diapsid reptiles might have originated.

Identification—*By row of crests on the back.*

79. *Hemidactylus*

Classification :

Phylum............**Chordata**		
Subphylum........**Vertebrata**		
Superclass........**Gnathostomata**		Characters same as those of *Sphenodon*.
Class...............**Reptilia**		
Subclass...........**Diapsida**		
Order...............**Squamata**	→	Lizards and snakes with horny epidermal scales or shield, quadrate bone movable, vertebrae procoelus and anal opening transverse.
Suborder........**Sauria or Lacertilia**	→	Lizard's body slender, limbs 4, pterygoid in contact with quadrate and eyelids movable.
Family..............**Gecknoidae**	→	Toes provided with adhesive pads.
Type.................*Hemidactylus*.		

Geographical distribution—*Hemidactylus* has world-wide distribution and is chiefly found in India, Europe, Asia, Africa, United States of America, Sri Lanka and China.

Habit and habitat—*Hemidactylus* is a common house lizard found in every home. **Nocturnal** in habit. During winter they hibernate under wood, logs and crevices of the walls. Wall lizards are adapted to walk on walls. They feed on insects and small invertebrates. *Hemidactylus* is a **fast runner.**

Comments :

(1) *Hemidactylus* is commonly known as **wall lizard.**

(2) Body is slender, measuring 25 cm. in size and covered with minute small scales and divided into **head**, **trunk** and **tail**.

(3) Head is triangular containing eyes, nostrils and **external ear opening.**

(4) **Forelimbs** and **hind limbs** well developed. **Toes** are provided with rounded **adhesive** plates or **pads** for climbing.

(5) Tongue protrusible.

(6) Many wall lizards produce sound.

(7) Quadrate bone movable. Only supra-temporal arch present.

(8) Eyes lack movable **eyelids.**

(9) **Vertebrae** amphicoelus. (10) Egg shells calcified.

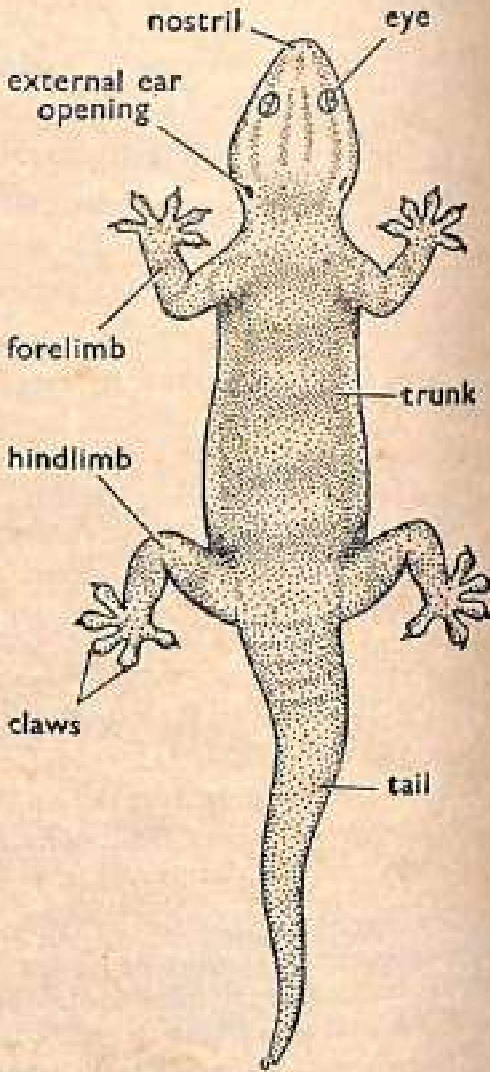


Fig. 3-81. *Hemidactylus*.

Special feature—The tail is broken from any place and again **regenerates**, although small in size; because vertebrae do not regenerate. The tail contains **intervening** unossified zone between vertebrae which are easily broken and then regenerate. This is called as **autotomy.**

The wall lizard is adapted to walk on walls, roofs and on smooth surfaces. The walking is effected by the **dilated digits**, which contain double series of **lamellae** and work under **vacuum principle**. The digits are first pressed over wall and then released gently to create a vacuum, by which they remain adhered to wall and are able to walk.

Identification—*Wall lizard is well familiar even to a lay-man and can easily be identified.*

80. Gecko

Classification—Same as those of *Hemidactylus.*

Geographical distribution—Gecko has cosmopolitan distribution but is specially found in Asian and European countries.

Habit and habitat—Same as those of *Hemidactylus.*

Comments :

(1) Gecko has similarity in appearance with *Hemidactylus* and is also commonly called as **house Gecko** or wall lizard.

(2) **Body** is divided into head, body and tail.

(3) **Head** is small, body and tail are elongated.

(4) **Fore** and **hind limbs** are adapted for walking on walls and smooth surfaces.

(5) **Digits** contain vertical **lamellae** functioning as adhesive pads.

(6) **Tail** regenerates if broken.

(7) **Intercentra** represented by bony elements formed by the ossification of the ventral portion of the disks.

(8) Geckos emit a peculiar little **yapping bark** when disturbed.

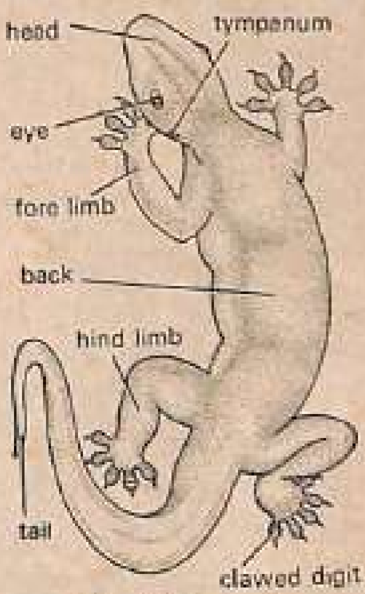


Fig. 3-82. Gecko.

81. *Phrynosoma*

Classification :

Phylum........**Chordata**
Subphylum...**Vertebrata**
Superclass...**Gnathostomata**
Class..........**Reptilia**
Subclass......**Diapsida**
Order..........**Squamata**
Suborder......**Lacertilia** or **Sauria**
} Characters same as those of *Hemidactylus.*
Family........**Iguanidae**
Type...........***Phrynosoma.***

Geographical distribution—*Phrynosoma* is a New World lizard and is chiefly found in Eastern Washington, Kansas to California and Mexico.

Habit and habitat—*Phrynosoma* is well adapted for desert life. It lives on dry ground and sandy places.

Comments :

(1) *Phrynosoma* is commonly known as **Horned toad.**

(2) Body of the animal is **broad, flat** and **spiny.** The scales of the head region are enlarged like **horns** and **spiny scales** are found all over the body.

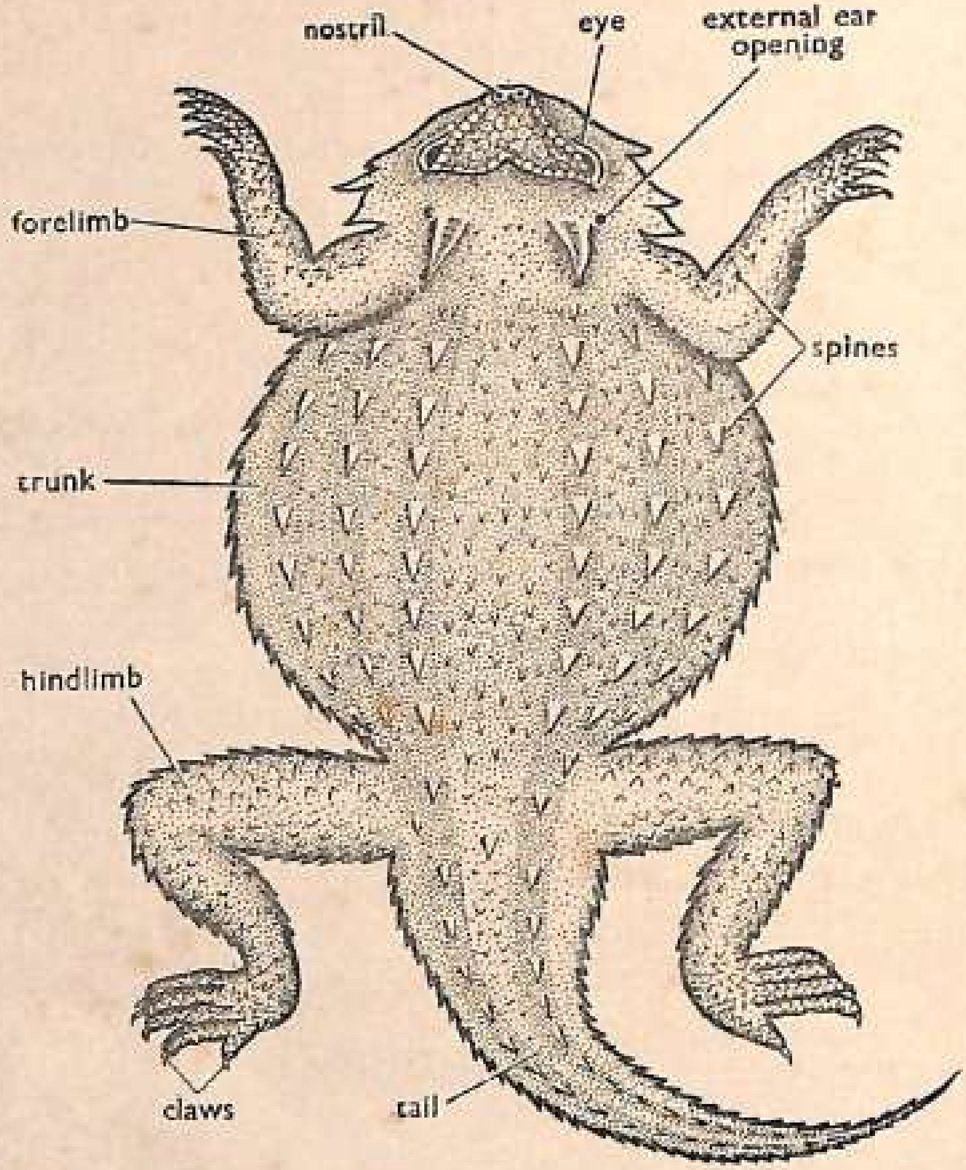


Fig. 3-83. *Phrynosoma*.

(3) The undersurface is covered with keeled **scales**.

(4) The dorsal surface is yellowish grey.

(5) Head contains 5 **spikes** on each side, one **post-orbital,** three **temporal** and one **occipital.**

(6) The sides of the lower jaw project in the shape of prominent ledges and are protected by a series of small spines.

(7) Undersurface of thigh contains pores in both sexes.

(8) Tail is short and spiny.

(9) **Tongue** is fleshy and non-protrusible. Eyelids are complete. Teeth are usually homodont.

(10) The nostrils are provided with valves, which prevent the sands to enter into nostrils.

Special feature—*Phrynosoma* is well adapted for arid zone living. During night it burrows.

Identification—*By rough skin and spines all over over the body.*

82. *Iguana*

Classification :

Phylum............**Chordata**
Subphylum.......**Vertebrata**
Superclass.......**Gnathostomata**
Class..............**Reptilia**
Subclass..........**Diapsida**
Order.............**Squamata**
Suborder.........**Lacertilia or Sauria**
Family............**Iguanidae**
Type...............*Iguana*.

(Phylum to Family:) Characters same as those of *Phrynosoma*.

Geographical distribution—*Iguana* is found in tropical countries. It is distributed in Mexico, West Indies and Southern and Central America.

Habit and habitat—*Iguana* is adapted for active running and climbing. It feeds on leaves, fruits, some insects and small vertebrates.

Comments :

(1) **Body** of the animal is **compressed** with **long tail** and is measuring 2 meters in length.
(2) The body contains **lance-like spines** along **mid-dorsal line**.
(3) The **neck** region contains **pendulous, extensible** and **fleshy** fold of skin, which helps in **courtship** and **rivalry**.
(4) **Limbs** are normal. (5) Teeth are **acordont** like and fixed to the sides of jaws.
(6) **Tongue** is fleshy and **non-protractile**. (7) **Eyelids** are complete.
(8) Both sexes have femoral pores. (9) Digits are clawed.
(10) The animal is also used as food by mankind in tropics.

Identification—*By median row of spines on back and tail.*

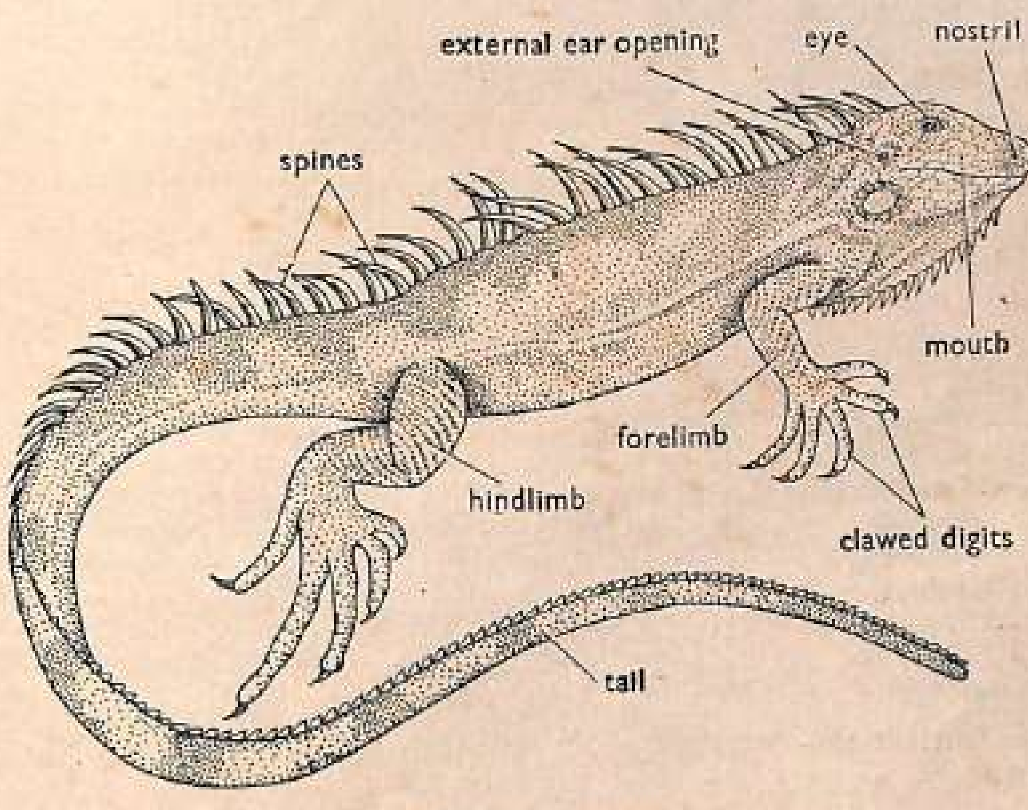


Fig. 3-84. *Iguana*.

83. Crotaphytus

Classification—Same as those of *Iguana.*

Geographical distribution—*Crotaphytus* is widely distributed in West Indies, Mexico, Southern and Central America.

Habit and habitat—*Crotaphytus* is a land lizard adapted for **fast running** and can jump like frog. It is **nocturnal, carnivorous, oviparous** and capable of changing colours.

Comments :

(1) *Crotaphytus* is commonly called as **collared** or **inflated** lizard.

(2) **Body** is divided into **head, trunk** and **tail.**

(3) Head is small containing **mouth, eyes, nares** and **tympanum.**

(4) Neck is small and in male possesses a **double black collar** and female has a slaty grey narrow collar.

(5) Limbs are stout, clawed and elongated.

(6) Eyes have movable eyelids.

(7) Tongue is small.

(8) Teeth pleurodont.

(9) **Vertebrae procoelus.**

(10) Tail is elongated and narrowly pointed.

Special feature—The lizard shows brilliant pigmentation specially during breeding season. The abdomen is **inflated.** The male is bright green coloured and the body surface is adorned with yellow spots. Females are grey coloured. The tail breaks in danger i.e. it shows **autotomy.**

Identification—*By collar and inflated abdomen.*

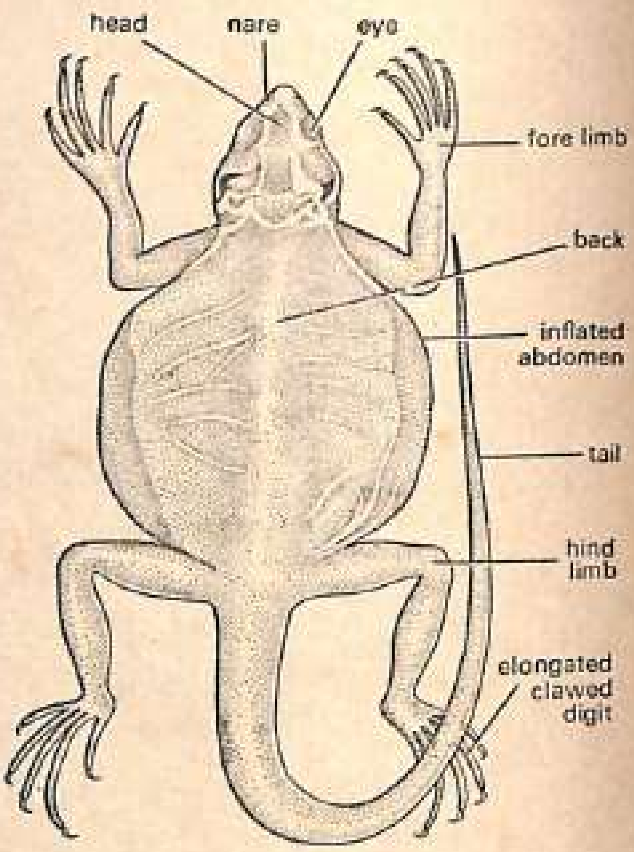


Fig. 3-85. *Crotaphytus.*

84. Draco

Classification :

Phylum............**Chordata**		
Subphylum.......**Vertebrata**		
Superclass.......**Gnathostomata**		
Class..............**Reptilia**	}	Characters same as those of *Iguana.*
Subclass...........**Diapsida**		
Order...............**Squamata**		
Suborder...........**Lacertilia**		
Family..............**Agamidae**		
Type................*Draco.*		

Geographical distribution—*Draco* is commonly distributed in Burma, India, Malayasia, Europe, Africa, Asia and Australia.

Habit and habitat—*Draco* is **arboreal**, living on trees. It feeds on small insects.

Comments :

(1) *Draco maculatus* is commonly known as **flying dragon or flying lizard.**

(2) Body of the lizard is dorso-ventrally compressed, measuring 15–22 cm. in length.

(3) The **neck** contains three hooks.

(4) Below the neck there are sac-like structures known as **gular pouches,** which are larger in males than females and they help in copulation.

(5) **Limbs** are normal.

(6) Teeth are **heterodont** and attached to edges of jaws.

(7) **Tongue** is thick and short. Some with throat sac or **dorsal spine.**

(8) Eyes are small with small eyelids.

(9) **Tympanum** behind the eyes.

(10) **Tail** long, slender and whip like. **Vertebrae procoelus.**

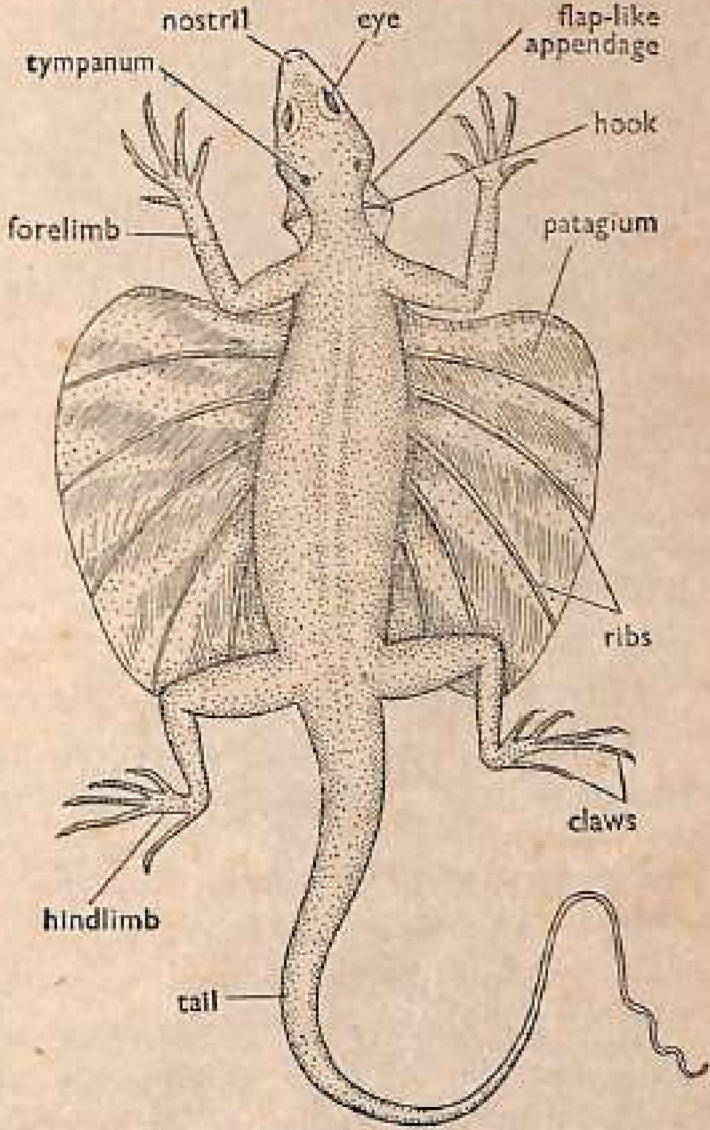


Fig. 3-84. *Draco.*

Special feature—*Draco* shows extreme adaptation for flying life and thus avoids its enemies on the ground. Most significant structures are membranous wings or patagia, which are formed by lateral expansion of skin and are supported by the patagial ribs used to volplane from a height. Flying lizard is adapted for climbing and gliding from higher to lower branches. *Draco* is brilliantly and beautifully coloured like flowers of tree in which it lives and thus it shows camouflage (mimicry).

Identification—*By patagium.*

85. *Moloch*

Classification :

Phylum	**Chordata**	Characters same as those of *Draco*.
Subphylum	**Vertebrata**	
Superclass	**Gnathostomata**	
Class	**Reptilia**	
Subclass	**Diapsida**	
Order	**Squamata**	
Suborder	**Lacertilia**	
Family	**Agamidae**	
Type	*Moloch horridus.*	

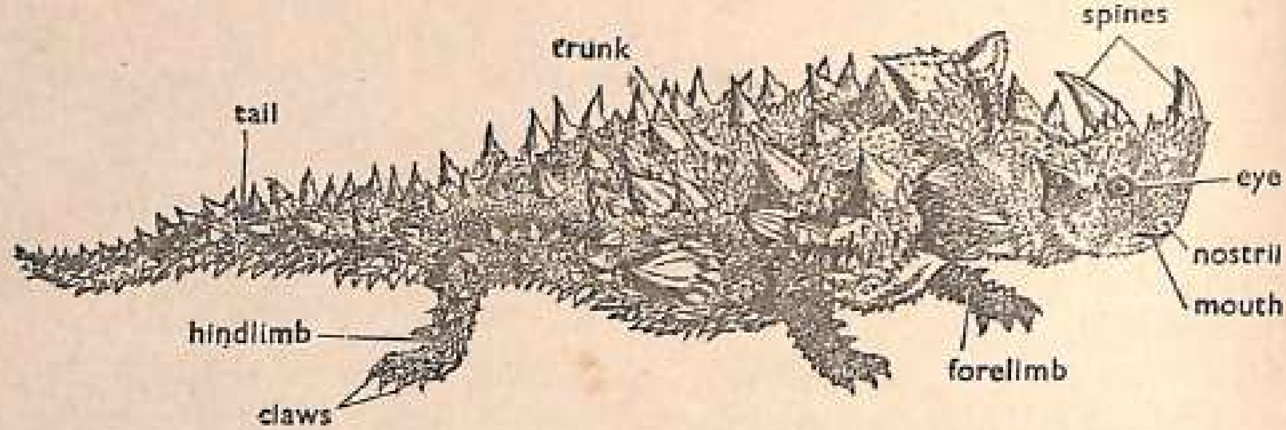


Fig. 3-87. Moloch.

Geographical distribution—*Moloch* is found in Australia.

Habit and habitat—*Moloch* is also adapted for dry conditions and it is ant-eater.

Comments :

(1) *Moloch horridus* resembles in appearance with the horned toad.

(2) **Skin** is rough and highly hygroscopic which absorbs moisture from the atmosphere.

(3) **Body** of the animal is elongated and is adorned with **heavy armour of scaly** spines. Head spines are largest. Spines cover the body on all sides. Tail spines and limb spines are smaller in size. Trunk spines are thicker.

(4) Head contains **mouth** and **nostrils.**

(5) Eyes well developed with eyelids and rounded pupil.

(6) Lateral teeth of the upper jaw are implanted horizontally and directed inwards.

(7) **Mouth** is small. (8) **Limbs** are normal (**pentadactyl**).

(9) The **heterodont** teeth are attached to the edges of jaws (acrodont).

(10) The tongue is thick and short.

86. Calotes

Classification :

Phylum	**Chordata**	Characters same as those of *Draco.*
Subphylum	**Vertebrata**	
Superclass	**Gnathostomata**	
Class	**Reptilia**	
Subclass	**Diapsida**	
Order	**Squamata**	
Suborder	**Lacertilia**	
Family	**Agamidae**	
Type	*Calotes.*	

Geographical distribution—*Calotes* is found in India, Malayasia and China.

Habit and habitat—*Calotes* is adapted for arboreal life and slight disturbance or any noise causes the lizard to run away swiftly. It feeds on small insects.

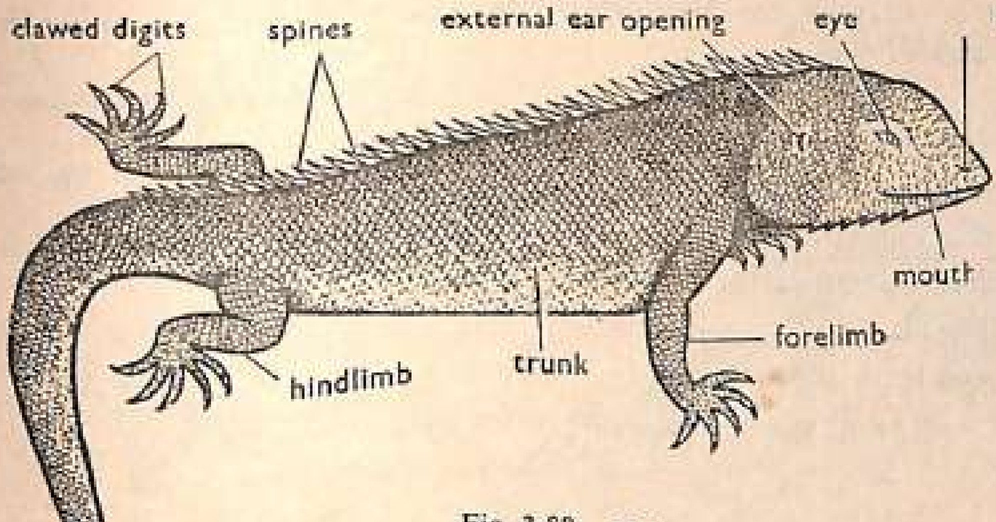


Fig. 3-88. *Calotes.*

Comments :

(1) *Calotes* is commonly known as **blood sucker** because of the red colour of neck. Its common name in Hindi is **girgitan.**

(2) **Body** is elongated, slender and measuring 30 cm. in length.

(3) Body is covered with rough scales and animal contains a **crest of spines** in mid-dorsal line.

(4) **Head** is broad and distinct.

(5) Gular pouches are absent.

(6) Limbs normal.

(7) Teeth usually differentiated (**heterodont**) and attached to edges of jaws (**acrodont**).

(8) Tongue short.

(9) Eyes with eyelids.

(10) Tail elongated and does not break.

Special feature—*Calotes* is also famous for colour changes. The original colour is olive green, but during courtship, colour changes to yellow and head becomes red. The colour changes are largely governed by temperature and environment and also by hormones from pituitary. The colour pigments are present in skin. During breeding season, male acquires brilliant colours and a gular pouch also develops in neck. The male changes colour during courtship and fights for female. Viviparous.

Identification—*By back spines and long pointed tail.*

87. *Mabuia*

Classification :

Phylum..................**Chordata**
Subphylum............**Vertebrata**
Superclass............**Gnathostomata**
Class....................**Reptilia**
Subclass...............**Diapsida**
Order....................**Squamata**
Suborder...............**Lacertilia**

} Characters same as those of *Calotes.*

Family..................**Sicncidae**
Type.....................*Mabuia.*

Geographical distribution—*Mabuia* is commonly found in India, Burma, Bangladesh and China.

Habit and habitat—*Mabuia* is adapted for burrowing life and consequently head contains small eyes.

Comments :

(1) *Mabuia* is commonly called as **skink.**

(2) It is, in first look, mistaken for small snakes.

(3) **Body** is reddish-brown in colour and vermiform.

(4) Entire body is covered with **small scales.**

(5) **Limbs** are slender and weak.

(6) **Femoral** pores absent and teeth pleurodont.

Special feature—This reptilian lizard shows retrogressive convergent evolution.

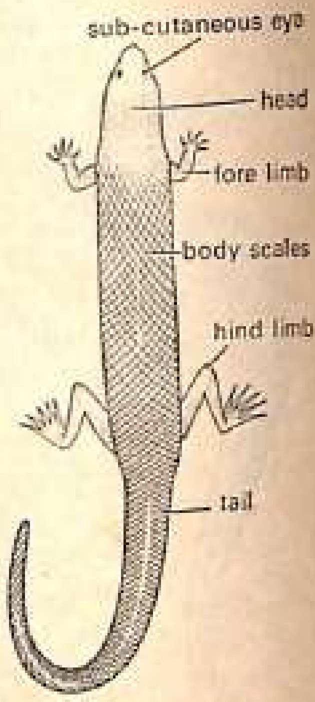


Fig. 3-89. *Mabuia.*

88. Chamaeleon

Classification :

Phylum..............**Chordata**
Subphylum.........**Vertebrata**
Superclass.........**Gnathostomata**
Class.................**Reptilia**
Subclass............**Diapsida**
Order.................**Squamata**
Suborder............**Lacertilia**
} Characters same as those of *Calotes*.
Family...............**Chamaeleontidae**
Type...................*Chamaeleon.*

Geographical distribution—*Chamaeleon* has world-wide distribution. It is found in Africa, Madagascar, Southern Arabia, Spain, Europe, Asia, Syria, India and Sri Lanka.

Habit and habitat—*Chamaeleon* is arboreal. It feeds on insects.

Comments :

(1) *Chamaeleon* has compressed body and elongated tail. It is adapted for arboreal life.

(2) **Head** contains a projected helmet formed by **squamosal** and **occipital** bones. **Head angular.**

(3) **Teeth** are **acrodont** and are found on maxillaries and mandible. **Premaxillaries** and palate without teeth.

(4) **Eyes** are large and covered with a thick glandular lid pierced by a small central opening for pupil. **Eyes** are adapted for **binocular vision;** they work independently while catching insects.

(5) **Tongue** projectile, tip of tongue club-shaped and **mucus** coated. The **tongue** can be **shot** several inches beyond head end to catch insect or prey.

(6) **Limbs** well developed. The toes are adapted for **grasping** and opposed 2 versus 3 digits. The fusion of digits is called **syndactyle.**

(7) **Tail prehensile.**

(8) **Tympanum** and **tympanic** cavity absent.

(9) **Quadrate** immovable and **vertebrae procoelus.**

(10) **Lungs** end in several diverticula or **air sacs** and end in body cavity.

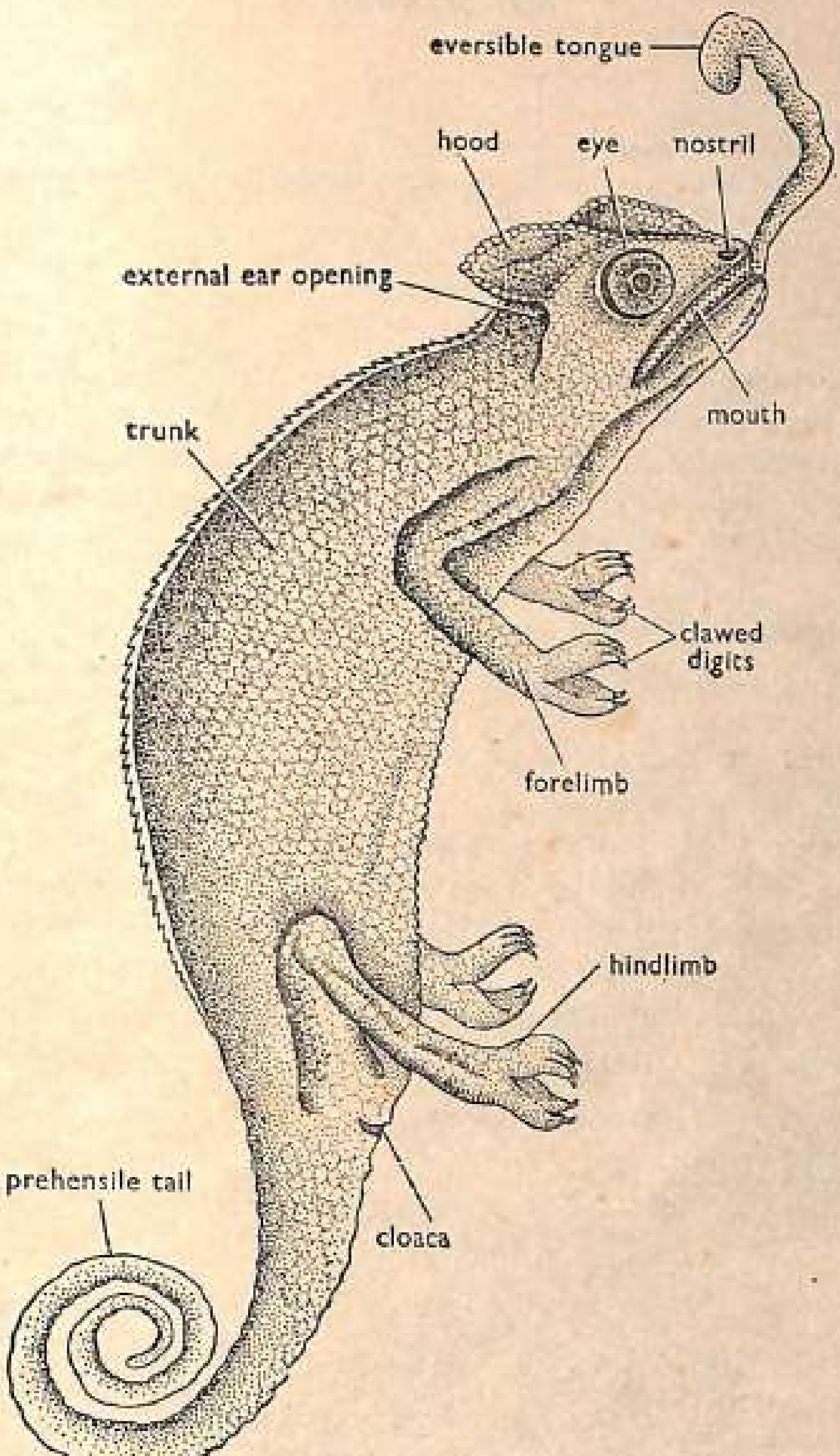


Fig. 3-90. *Chamaeleon.*

(11) **Organ of Jacobson** and sensory part of nose absent.

(12) **Proatlas** is found between atlas and skull.

Special feature—*Chamaeleons* are famous for their colour changes.

Identification—*By head-hood, prehensile tail and syndactylic limbs.*

89. *Varanus*

Classification :

Phylum......................	**Chordata**	Characters same as those of *Chamaeleon*.
Subphylum.................	**Vertebrata**	
Superclass.................	**Gnathostomata**	
Class..........................	**Reptilia**	
Subclass....................	**Diapsida**	
Order.........................	**Squamata**	
Suborder....................	**Lacertilia**	
Family........................	**Varanidae**	
Type...........................	*Varanus*.	

Geographical distribution—*Varanus* is distributed in Africa, Southern Asia, south-east islands of Australia, India, Sri Lanka and Malaya.

Habit and habitat—*Varanus* inhabits dry places under stones and rocks and it leads a burrowing life. It feeds upon tortoises, squirrels and dead bodies of other animals. It is most active at night. Monitor lizards are **carnivorous** and **semiaquatic.**

Comments :

(1) *Varanus* is commonly known as **Monitor lizard.**

(2) **Body** of the animal is elongated with especially large **trunk,** measuring 60–90 cm. in length.

(3) **Body** is covered with bead-like **scales** having large brownish, black and orange patches, which act like warning colours.

(4) **Neck** and tail are long. **Tail** is thickened and serves as **storehouse for fat.**

(5) The limbs are stout, well developed and adapted for swift movement, but they can hardly lift the body up from the ground.

(6) **Teeth** are large, pointed and pleurodont.

(7) The **tongue** is long, smooth, deeply forked and **protrusible.**

(8) **Eyes** are fixed. (9) Trunk stout.

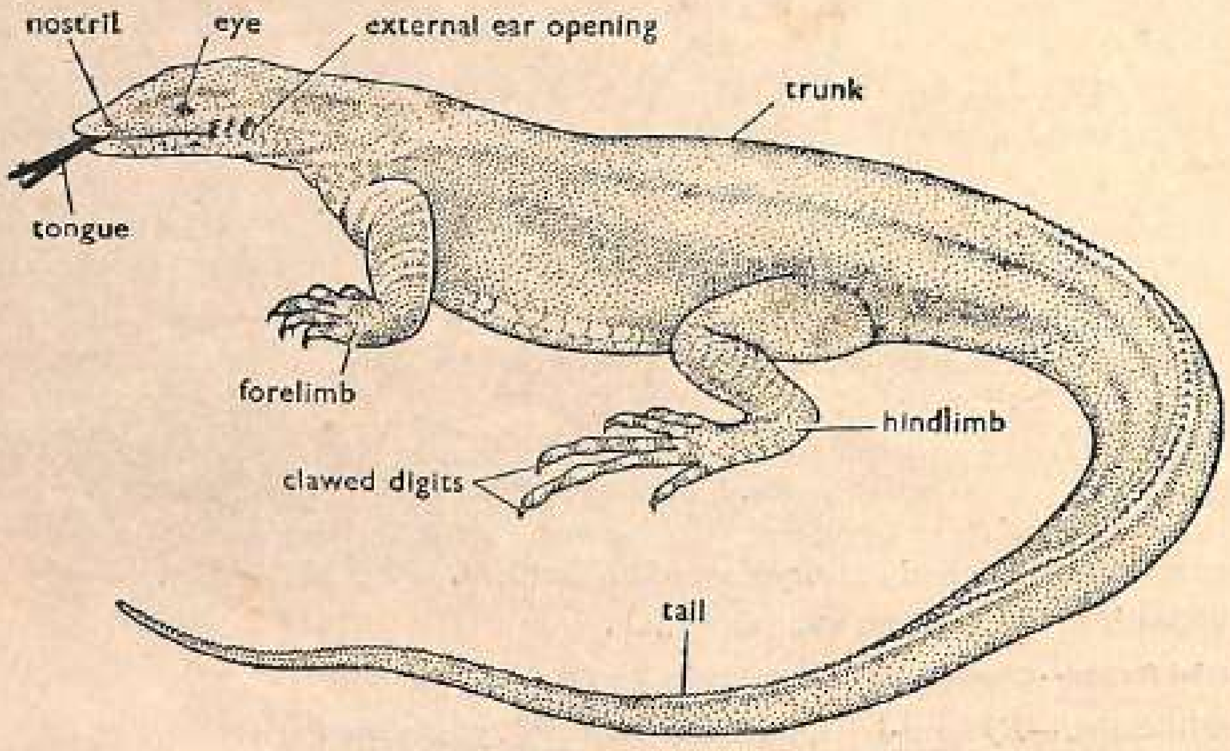


Fig. 3-91. *Varanus*.

90. *Heloderma*

Classification :

Phylum............Chordata
Subphylum........Vertebrata
Superclass........Gnathostomata
Class................Reptilia
Subclass...........Diapsida
Order..............Squamata
Suborder..........Lacertilia
Family............Helodermatidae
Type................*Heloderma.*

(Phylum to Suborder:) Characters same as those of *Chamaeleon*.

Geographical distribution—*Heloderma* is found in deserts of Mexico and U.S.A.

Habit and habitat—*Heloderma* lives in dry places under rocks and in burrows. It is a clumsy, sluggish animal which feeds on snake eggs, insects and lizards.

Comments :

(1) *Heloderma* is commonly called as **Gilla monster** or **Hella monster**.

(2) The animal measures about 60 cm. in length and body is covered with **ugly tubercles**.

(3) Body contains **brilliant black** and **orange scales** forming coloured patches.

(4) The **tail** is thick and blunt having reserve fat.

(5) **Trunk** and **tail** stout and rounded.

(6) **Dorsal scales** bead-like over bony tubercles (osteoderms). Ventral scales flat.

(7) Tongue fleshy, protrusible.

(8) The **limbs** are short, powerful and well developed. It is capable of swift movement.

(9) **Teeth** pleurodont, fang like and contain labial poison glands which open on outer "**gum**" of lower jaw.

(10) *Heloderma* lays eggs in the nest formed in sandy soil.

Special feature—*Heloderma* is the only **poisonous lizard**. The **poison apparatus** comprises of a modified **sublingual** salivary gland that secretes a poisonous fluid. Poison glands open on outer **gum** of lower jaw. **Venom** is potent; bite is fatal to small animals, and rarely to man.

Identification—*By bead-like scales, tubercles, coloured patches and stout trunk.*

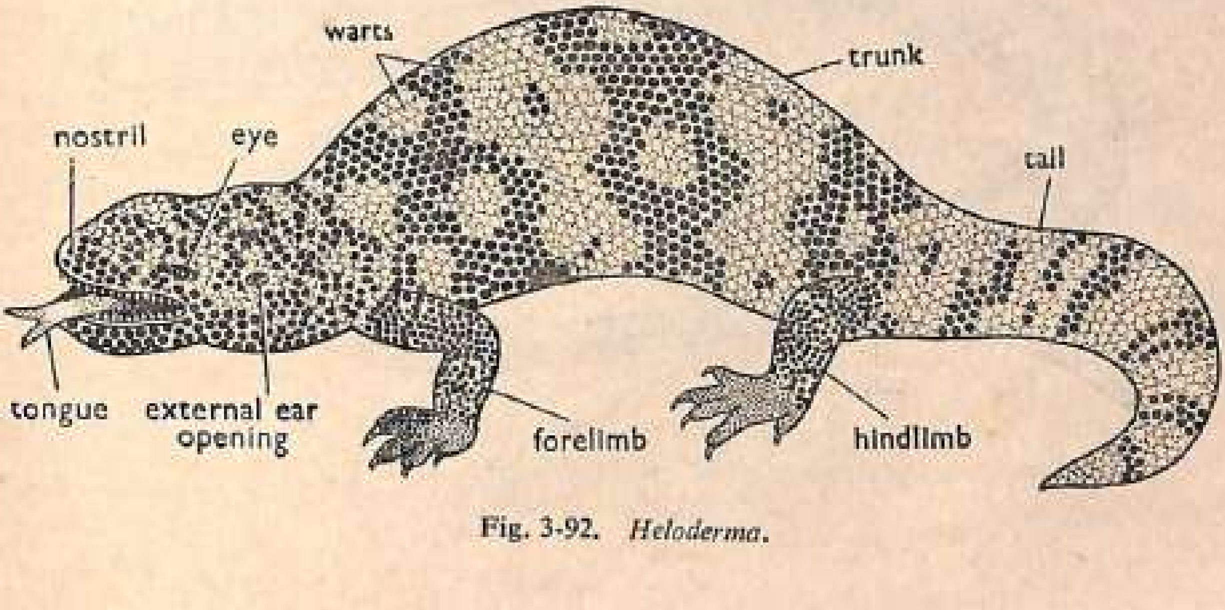


Fig. 3-92. *Heloderma*.

91. Ophiosaurus

Classification :

Phylum............**Chordata**	Characters same as those of *Chamaeleon*.
Subphylum.......**Vertebrata**	
Superclass........**Gnathostomata**	
Class...............**Reptilia**	
Subclass...........**Diapsida**	
Order...............**Squamata**	
Suborder..........**Lacertilia**	
Type...............*Ophiosaurus.*	

Geographical distribution—*Ophiosaurus* is commonly found in U.S.A., Mexico, Africa, Western Asia and India. The Indian species is *O. gracilis* found in the eastern Himalayas.

Habit and habitat—*Ophiosaurus* lives in burrows.

Comments :

(1) The animal lives in burrows and is called as **glass snake.**

(2) The body length is short but snake like.

(3) **Body** is covered with epidermal scales and below scales body plates are present which have hard texture.

(4) Distinct neck is absent. (5) **Eyes** are reduced due to burrowing life.

(6) **Body scales** are rectangular and arranged in circular and longitudinal rows. A ventro-lateral longitudinal fold of skin terminates into a locomotory spike near the cloaca.

(7) *Ophiosaurus* is differentiated from snakes. (8) It is a limbless lizard.

(9) Pigmentation is greenish brown with longitudinal stripes.

(10) Tail breaks off more easily than that of other lizards.

Special feature—*Ophiosaurus* is distinguished from snakes by a narrow gape of mouth, movable eyelids and tympanic holes and from limbless amphibia by the presence of epidermal scales and a long tail. A group of American limbless lizards (worm lizards) have head shields, **annular bands** like earthworms and no scales.

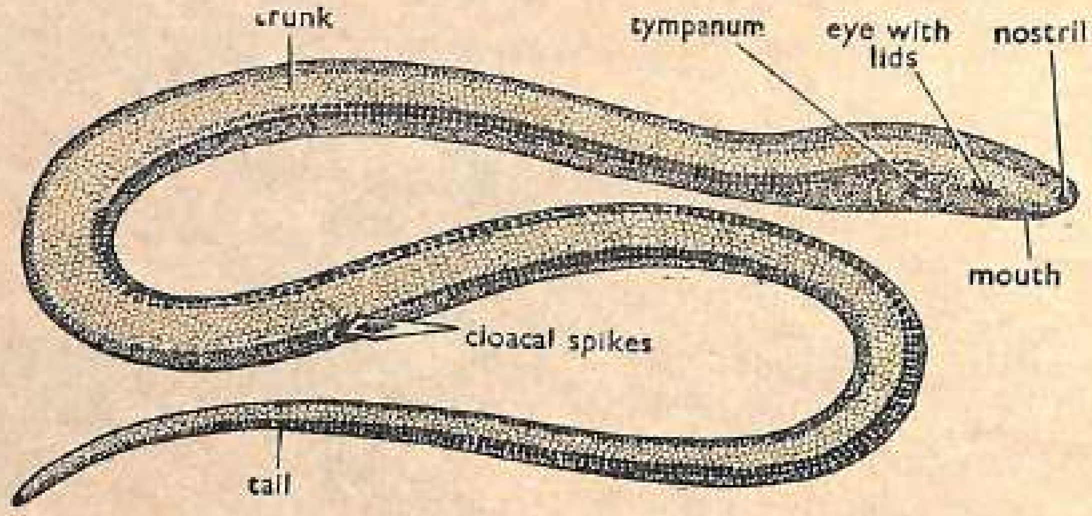


Fig. 3-93. *Ophiosaurus.*

SNAKES

Man has always feared and worshipped snakes in India. Snake bites are often fatal in case of poisonous snakes. A detailed account is given below in order to distinguish the poisonous and non-poisonous snakes.

A. NON-POISONOUS SNAKES—Pythons, trinket snakes and racer snakes.

B. POISONOUS SNAKES—Cobra, Krait, Vipers, Russell's viper, saw-scaled vipers.

The scales are of taxonomic importance. The snakes are classified on the basis of scales. Scales also help in distinguishing poisonous and non-poisonous snakes. The snakes contain shields of scales in the head. The identifying shields are named as internasal, nasal, prefrontal, loreal, pre-ocular, frontal, supra-ocular, post-ocular, parietal, mental, occipital, pit, supra-labial and infra-labial. The anterior sublingual and posterior sublingual constitute ventral or lower side of head. In primitive snakes, sandy boa and vipers, the head scales are minute and undifferentiated. The dorsal scales are elliptical, rhomboid, tuberculated, serrated and keeled. In primitive snakes, the head scales are semicircular. The following chart is designed to differentiate poisonous and non-poisonous snakes.

A. NON-POISONOUS SNAKES

(a) Scales on body semicircular, tail blunt, dorsal and ventral scales undifferentiated (Fig. 3-94). — (Blind snakes) *Typhlops*

(b) Scales on body distinct and ventral scales are found along belly.

(1) Ventral scales partially cross the belly, eyes present. — *Uropeltis scellatus*

(a) Rough tail and tail end blunt. — Sand boa

(b) Tail smooth, having blunt end (Fig. 3-96). — *Eryx conicus johnii*

(c) Long tail provided with spurs (Fig. 3-95). — *Python molurus*

(2) Ventral scales completely across the belly. Head covered with symmetrical plates, hypophyses may or may not be present. — Colubridae snakes

B. POISONOUS SNAKES

Ventral scales partially or completely across the belly. Head shields without loreal. Tail cylindrical except in sea snakes. Hypophyses present. Teeth modified to form fangs.

(a) Ventral scales partially across the belly. Tail flattened, oar like. Ventral scales form ventral ridge. Eyes present at anterior end of head. Poison fangs are present (Fig. 3-100). — *Hydrophis*

(b) Ventral scales complete across the belly. Head and tail long. Poison fangs small and naked. — **Elapidae**

(1) Median dorsal scales hexagonal. The colour of the body steel-blue with white bars. — *Bungarus caerulgus* (Krait)

(2) The colour of the body yellow, with black cross bands and face contains a black stripe. (Fig. 3-102). — *Bungarus fasciatus*

(3) Hooded snake. Eyes contain round pupil. The dorsal frontal shields truncated. Three small post-ocular scales behind the eyes. Supra-labials 7 in number. Caudal scales paired. The hood contains monocellate or binocellate marks and 2–3 series of black bands on ventral surface. A triangular shield between 4th and 5th infra-labial. — *Naja naja* (cobra)

(4) Hooded snake. Frontal shield not truncated. The triangular shield between 4th and 5th infra-labial absent. Two large occipital shields behind parietals. Poison fang present. The hood contains yellow cross stripes dorsally and two black bands ventrally with corner black spots (Fig. 3-103). — *Naja hanna* (king cobra)

(5) Hood absent. Post-ocular 2, supra-labial 6. 3rd and 4th supra-labial touching eye. 3-4 teeth behind poison fang. The colour of body light brown or reddish with black stripes or spots over head. — *Callophis* (coral snake)

(c) Ventral scales on the body. Tail elongated. Head triangular and containing minute shields. Poison fangs erectile and sheathed. Eyes contain vertical pupil. **Viperidae**

(1) Dorsal scales oblong with median vertical ridge and with 3 rows of elliptical spots on body. *Russell's viper*

(2) Side dorsal scales serrated which make continuous sound. Head contains arrow mark. Small snakes. Locomotion by side winding. The poison fangs erectile and sheathed. *Echis carinatus*

(3) Between pre-ocular and loreal there is a pit behind nasal. Eyes contain vertical pupil. Body scales keeled. Tip of head raised in rostral region. Poison fangs erectile and sheathed (Fig. 3-105). **Pit viper**

92. *Typhlops*

Classification :

Phylum............**Chordata**
Subphylum.......**Vertebrata**
Superclass........**Gnathostomata**
Class................**Reptilia**
Subclass... ....**Diapsida**
Order..............**Squamata**

} Characters same as those of *Heloderma*.

Suborder...........**Ophidia** → Snakes. Limbs, feet, ear openings, sternum and urinary bladder absent. Mandibles joined anteriorly by ligament. Tongue slender, bifid and protrusible. Left lung reduced.

Family............**Typhlopidae**
Type................*Typhlops* (Blind snake).

Geographical distribution—*Typhlops* is widely distributed in Europe, Asia, Africa, America, Australia, India tropics, and subtropics of both hemispheres.

Habit and habitat—*Typhlops* is a burrowing snake. It feeds on small insects, earthworms and soft larval insects.

Fig. 3-94. *Typhlops*.

Comments :

(1) *Typhlops* is commonly known as **blind snake.**

(2) **Body** is elongated, cylindrical measuring about 175-180 mm.

(3) The animal looks like earthworm and is of dark chocolate colour.

(4) Body is covered with **overlapping scales.**

(5) There is no distinct head and also there is **no differentiation** between **dorsal** and **ventral** scales.

(6) **Lower jaw** without teeth, **maxilla** toothed and transversely placed, **ectopterygoid** and **squamosal** absent and **pterygoid** separate from quadrate.

(7) **Rostral, nasal, ocular** and **pre-ocular** shields are larger.

(8) Eyes are indistinct and covered with scales.

(9) Scales in multiple rows over whole body. (10) Eyes without eyelids and immobile.

(11) **Limbs, feet, ear openings, sternum, urinary** bladder absent. **Mandibles** join anteriorly by ligament. **Tongue** slender bifid and protrusible. Left lung reduced.

93. Python

Classification :

Phylum.................**Chordata**		
Subphylum...........**Vertebrata**		
Superclass............**Gnathostomata**		
Class...................**Reptilia**		Characters same as those of *Typhlops*.
Subclass.............**Diapsida**		
Order...................**Squamata**		
Suborder..............**Ophidia**		
Family..................**Boidae**		
Type....................*Python* (Ajgar).		

Geographical distribution—*Python* has world-wide distribution except New Zealand.

Habit and habitat—Pythons are found especially in woody regions and they climb on trees. They are found in **dry, rocky** and sandy places. They **kill** birds, goats, sheep, deer, cows, dogs, horses and even tigers. They can **swim** in water.

Comments :

(1) *Python* is commonly known as **Ajgar** and is a favourite snake in a **serpentorium.**

(2) **Body** of the animal is **huge, massive, voluminous** and measuring about **10 meters** in length, and weighing **110 kilograms.**

(3) Body is covered with small scales in 60–75 rows.

(4) *Python* is **non-poisonous** with **prehensile** tail.

(5) The **vestigial hind limbs** and **pelvic girdle** exist as **spurs** on each side of the anus.

(6) **Eyes** are free and functional with vertical **pupil.**

(7) **Mandibles, pterygoids, palatines, maxilla** and **premaxilla** contain teeth. Maxilla, palatine and pterygoid movable.

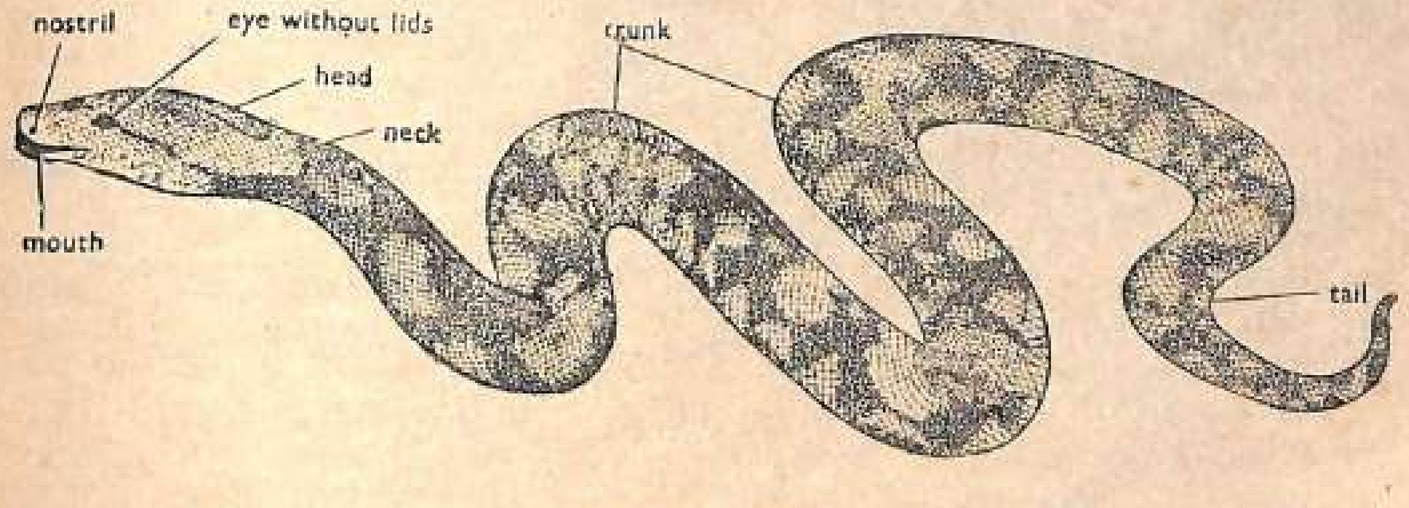


Fig. 3-95. Python.

(8) The **rostral scale** of head contains a deep **thermo-receptive pit.**

(9) Lancet-shaped brown mark present over head. **Parietal, loreal** and temporal regions are covered with irregular plates. **Supra-labials** are 11–13, 1st two contain pit and 7th touching eye. **Infra-labials** 16–18.

(10) **Oviparous**.

Special feature—*Python* is very lethargic but during feeding and on seeing prey, it becomes very active, and coils around the prey. It kills the prey by pressing by its massive muscular body and gradually it shoves the prey. Indian python is *P. molani.*

Identification—*By massive looking body and other above characters.*

94. *Eryx*

Classification :

Phylum............Chordata
Subphylum........Vertebrata
Superclass........Gnathostomata
Class...............Reptilia
Subclass............Diapsida
Order...............Squamata
Suborder...........Ophidia
Family..............Boidae

} Characters same as those of *Python*.

Type...............*Eryx johnii* (Dumuhi).

Geographical distribution—*Eryx* is found in all over India, Sri Lanka, Africa and Asia.

Habit and habitat—*Eryx* is found in sandy regions. It remains hidden in sand and feeds on lizards, frogs and mice.

Comments :

(1) *Eryx conicus* is commonly called as **sand boa,** the common **double-mouthed** snake **(dumuhi)**.

(2) Snake is elongated with pinkish grey and brown irregular patches all over the body. Ventral surface is yellowish.

(3) It measures one meter in length.

(4) Body scales are small, 40–55 rows and sometimes keeled in tail region.

(5) Eyes are small with vertical pupil. Eyes reduced due to burrowing life.

(6) Head and neck indistinguishable.

(7) Head scales primitive and 3 scales enlarged.

(8) Nostrils are slit like.

(9) Tympanum absent.

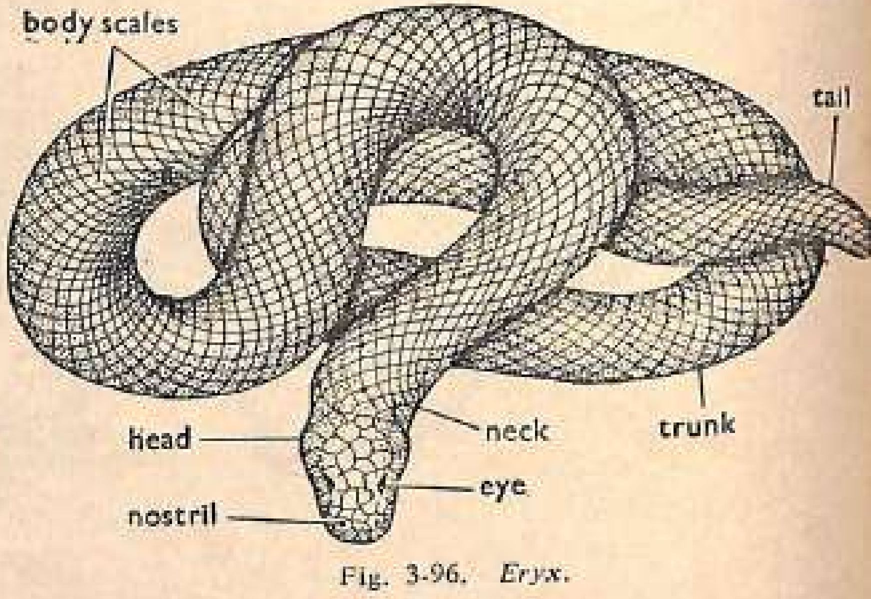


Fig. 3-96. *Eryx*.

(10) Ventral scales do not run across the body.

Special feature—*Eryx* is characterized by the blunt tail end looking like head. Sometimes snake crawls back and hence it is called as double-headed snake but actually there are no second mouth and head. It kills the prey by constriction.

Identification—*By blunt tail end.*

95. *Ptyas* (Zamenis)

Classification :

Phylum..............**Chordata**
Subphylum.........**Vertebrata**
Superclass.........**Gnathostomata**
Class................**Reptilia**
Subclass............**Diapsida**
Order................**Squamata**
(Phylum to Order: Characters same as those of *Eryx*.)
Suborder............**Ophidia**
Family..............**Colubridae** → Common snakes.
Type..................*Ptyas mucosin* (Dhaman).

Geographical distribution—*Ptyas* is commonly found in India, Burma, Java, Europe, Asia, Africa, North and Central America.

Habit and habitat—*Ptyas* is found on plains. It can climb trees and it feeds on frogs, toads, mammals and even snakes and lizards.

Comments :

(1) *Ptyas* is commonly called as **Rat snake** or **Dhaman**.

(2) **It attacks** forcibly like whip and hence it is also called as **rope snake**.

(3) **Body** is elongated with dirty, yellow colour and is measuring about 3 meters in length.

(4) **Scales** in 16–17 rows and some scales slightly keeled.

(5) **Eyes** are large with round pupil and golden iris.

(6) **Head** differentiated from neck.

(7) **Loreal** region is concave having **pre-subocular, nasals** and **nostrils** and **supra-ocular** forming a **ridge** on eye.

(8) *Ptyas* is **non-poisonous** and an **active snake**.

Special feature—**Rat snake bites** viciously and coils around the victim firmly by its prehensile tail. It **emits** foul odour and secretes black secretion from the anal glands. It is oviparous.

Identification—*By ridge on eye.*

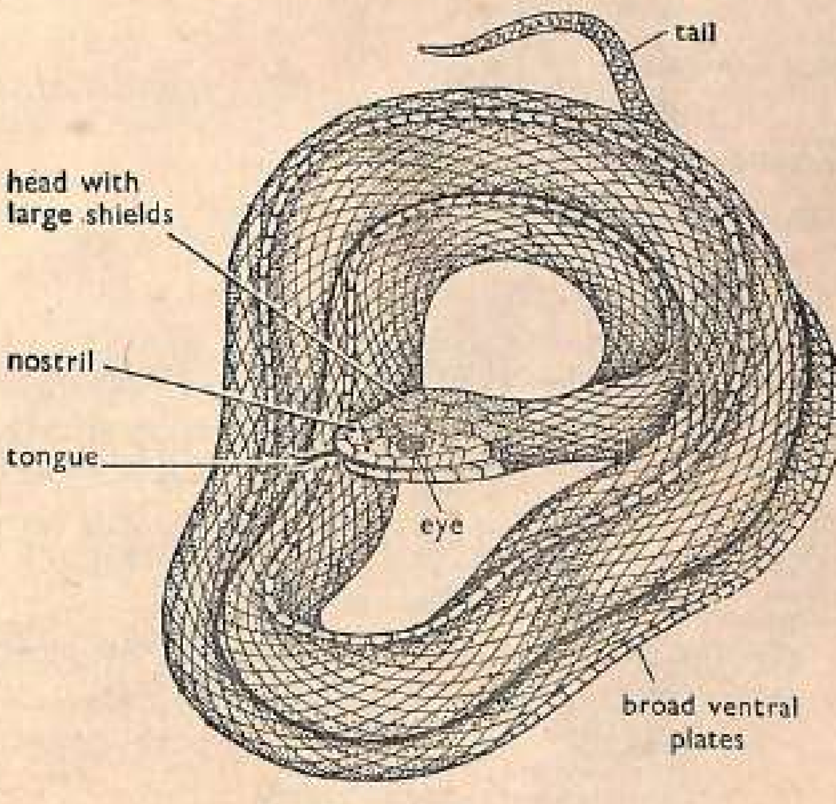


Fig. 3-97. *Ptyas* (*Zamenis*).

96. Natrix

Classification : Same as those of *Ptyas.*

Geographical distribution—*Natrix* is widely distributed in U.S.A., Mexico, North Africa and India. *Natrix piscator* is the common Indian snake.

Habit and habitat—*Natrix* is found in fresh water, hidden under water vegetation or grasses. It is diurnal, oviparous and feeds on fishes and frogs.

Comments :

(1) *Natrix* is commonly called as **water snake.**
(2) **Body** is covered with chess-board-like black spots.
(3) Entire body is covered with **epidermal scales.**
(4) **Head scales** are large, called as shields.
(5) **Belly scales** are plate-like, while side scales are smaller.
(6) **Fangs absent, teeth present, non-poisonous.**
(7) **Facial bones** movable.
(8) Squamosal loosely attached to skull.
(9) **Maxillaries** horizontal, forming most of upper jaw.
(10) Both jaws with teeth but **fangs** absent. Tympanum absent.

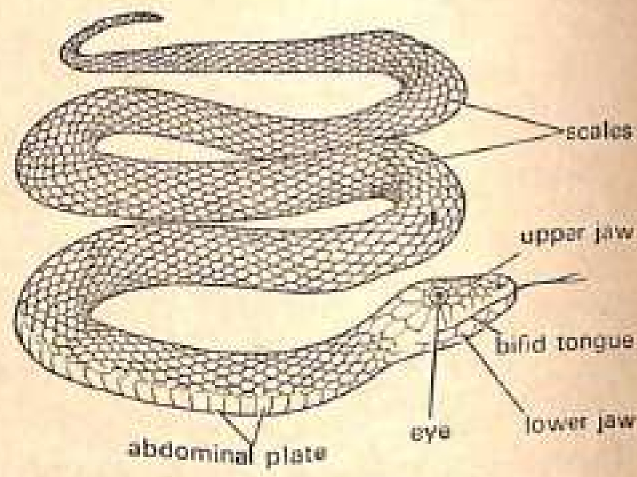


Fig. 3-98. *Natrix.*

Identification—*By chess-board-like black spots.*

97. Dendrophis

Classification : Same as those of *Ptyas.*

Geographical distribution—*Dendrophis* is found in Asia, South America and Australia.

Habit and habitat — *Dendrophis* is adapted for arboreal life. It lives on trees and feeds on frogs. **Diurnal and oviparous.**

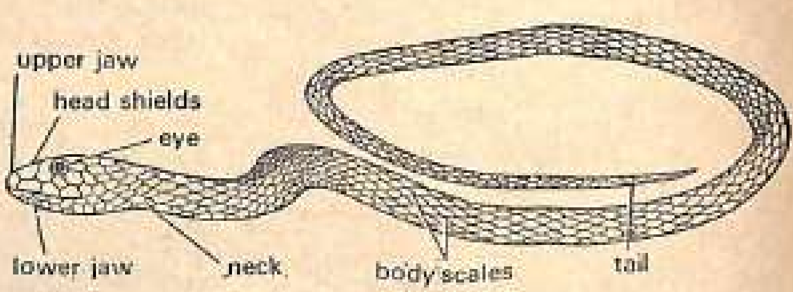


Fig. 3-99. *Dendrophis.*

Comments :

(1) *Dendrophis* is commonly called as **tree snake.**
(2) It measures about 6 feet in length.
(3) The snake is **elongated** and cylindrical with pointed tail.
(4) **Head** is large and covered by large plate-like scales. Scales are **keeled** and form 13 or 15 rows.
(5) Scales of vertebral row enlarged.

(6) **Ventrals** have a pair of suture-like lateral **keel** and **notch** on sides which helps in climbing.

(7) **Belly scales** are plate-like, while side scales are small.

(8) Body contains yellow stripes. (9) **Fangs** absent but teeth present.

(10) Eyes covered with transparent and fused membrane. **Tympanic membrane** absent.

Special feature—*Dendrophis* is a harmless and non-poisonous snake.

Identification—*By keel and notch on sides.*

98. *Hydrophis*

Classification :

Phylum............Chordata
Subphylum.......Vertebrata
Superclass........Gnathostomata
Class...............Reptilia
Subclass..........Diapsida
Order...............Squamata
Suborder...........Ophidia
} Characters same as those of *Ptyas*.
Family..............Hydrophidae → Sea snakes.
Type...............*Hydrophis* (Water snake).

Geographical distribution—*Hydrophis* is found in India, along the Pacific Coast from Southern Mexico to northern South America, in the Bay of Bengal and Malaysia Archipelago.

Habit and habitat—*Hydrophis* is commonly found in water. It **feeds** on fishes.

Comments :

(1) *Hydrophis* is commonly called as **sea snake** or **water snake**.

(2) **Body** is elongated, measuring about 2 meters in length.

(3) The body is laterally compressed.

(4) The scales are small.

(5) The general **pigmentation is dark olive green** above with yellowish cross bars and whitish area below.

(6) **Head** is indistinct and covered by **large shields**.

(7) **Ventral** scales are small. **Loreal** shield is absent. One pre-ocular, 2 post-oculars and 7–8 supra-labials present. 3rd and 4th supra-labials touch the eyes.

(8) **Maxillary** teeth 14–18 behind the poison fangs.

(9) Eyes small with rounded pupil.

(10) Water snakes are oviparous and they come out of water for egg laying.

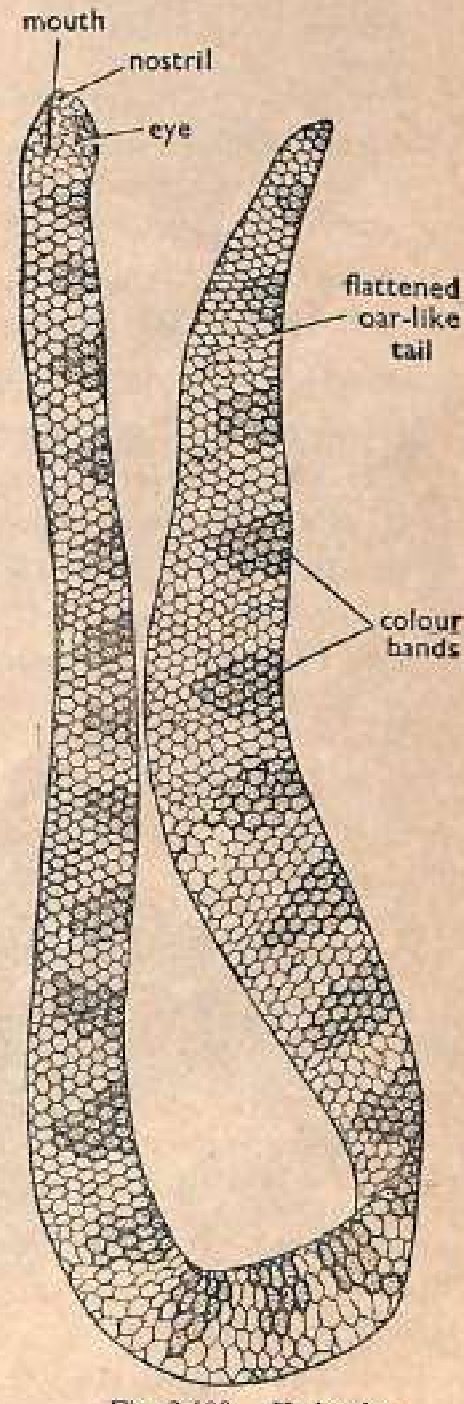


Fig. 3-100. *Hydrophis*.

Special feature—*Hydrophis* is a deadly poisonous or venomous snake and very dangerous to mankind. Neurotoxic venum. The tail is compressed and adapted for **swimming**. It is broader than the body.

Identification—*By laterally compressed tail and head shields.*

99. Crotalus

Classification :

Phylum..............**Chordata**
Subphylum........**Vertebrata**
Superclass.........**Gnathostomata**
Class..................**Reptilia**
Subclass............**Diapsida**
Order.................**Squamata**
} Characters same as those of *Ptyas*.
Suborder...........**Ophidia**
Family...............**Viperidae**
Type.................*Crotalus* (Rattle-snake).

Geographical distribution—*Crotalus* is found in U.S.A. and Mexico. North America contains *C. horridus*, a common rattle-snake of U.S.A. *C. confluentus* is found in western America. About 40 species and varieties are found in western hemisphere and 20 in U.S.A.

Habit and habitat—*Crotalus* is adapted for terrestrial life. During winter season it hibernates underground. It is **carnivorous, nocturnal.** It feeds on small mammals.

Comments :

(1) *Crotalus* is commonly called as **Rattle-snake**.
(2) Body is elegantly elongated, measuring 2–3 meters in length.
(3) Handsome **pigmentation pattern**. The general surface is greyish brown with dark bands.
(4) **Head** contains **small scales** on upper side. It has a **sensory pit** between eye and nostril. It is distinct from neck.
(5) Two pairs of **internasals** present.

Fig. 3-101. *Crotalus* (Rattle-snake).

(6) **Fangs** are long and **movable** and folded when not in use.

(7) Head contains small nostrils and ventral mouth.

(8) Tongue bifid and protrusible. (9) Eyes are small without eyelids.

(10) Hood triangular in shape.

Special feature—The snake is immediately characterized by the presence of a **rattle** at the end of the tail. **Rattle** is derived from moulting epidermis consisting of 10–12 hollow segments. During fast locomotion, tail is vibrated and rattle produces characteristic rattling sound which warns the intruder. It is a deadly poisonous snake. It is **carnivorous** and **viviparous**.

Identification—*By rattle in tail.*

100. Bungarus

Classification :

Phylum............**Chordata**
Subphylum.......**Vertebrata**
Superclass.......**Gnathostomata**
Class..............**Reptilia**
Subclass..........**Diapsida**
Order..............**Squamata**
Suborder..........**Ophidia**
} Characters same as those of *Crotalus*.

Family............**Elapidae** → Terrestrial and poisonous snakes.
Type...............*Bungarus* (Krait).

Geographical distribution—*Bungarus* is found in South-east Asia, all over India and Malaya.

Habit and habitat—*Bungarus* is a common snake, found in the crevices of walls, under the logs and stones. It is nocturnal and feeds on smaller snakes, toads and mice. It is shy and considerate. It **attacks** only when disturbed or trodden with foot.

Comments :

(1) *Bungarus* is commonly called as **Krait.**

(2) **Body** is elongated and **cylindrical**, measuring one meter in length.

(3) The **colour** of the body is **steel-blue** and **dark-blue.**

(4) The dark-blue patches alternate with white cross bars.

(5) The body contains enlarged chain of hexagonal scales on the dorsal side.

(6) **Head** is not differentiated from the neck. **Loreal absent. Post-ocular, preocular** and **supra-labial** 2, 1 and 7 in number respectively. **Fangs small.**

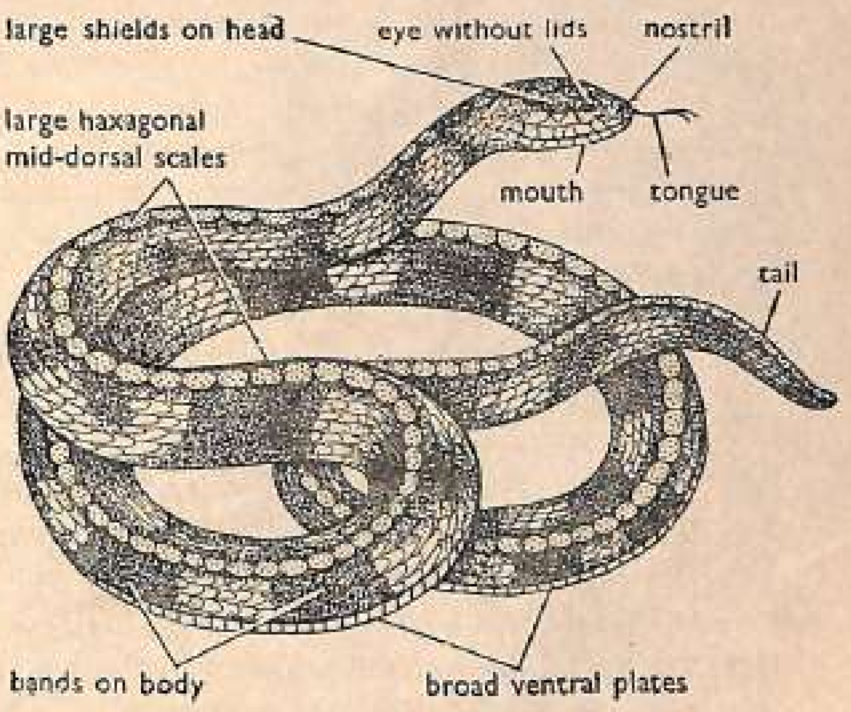


Fig. 3-102. *Bungarus.*

(7) **Eyes** are of moderate size with round pupils. **Tongue bifid** and protrusible.

(8) **Scales** are smooth forming 13–17 rows. Ventrals are 194–234 and caudals 42–52.

(9) Enlarged chain of **hexagonal scales** is present on the dorsal side and the ventral scales beyond the anal region are in a single row.

(10) **Oviparous.** Female shows parental care.

Special feature—*Bungarus* is a deadly poisonous snake, the venom being more poisonous than that of cobra. Its venom is neurotoxic affecting brain. After an hour of the bite, the victim feels sleepy and if immediate anti-venom is not given, the patient may die.

Identification—*By hexagonal scales on dorsal side.*

101. *Naja* (Nag)

Classification :

Phylum..........**Chordata**
Subphylum......**Vertebrata**
Superclass......**Gnathostomata**
Class.............**Reptilia**
Subclass.........**Diapsida**
Order.............**Squamata**
Suborder.........**Ophidia**

} Characters same as those of *Bungarus*.

Family............**Elapidae**
Type...............*Naja* (Nag or Indian Cobra).

Geographical distribution—*Naja* has wide distribution, found in India, Africa, China, Philippines, Tasmania, Australia, New Guinea and Egypt.

Habit and habitat—**Cobra** is diurnal, shy, living in holes, understones, mud walls and in thick vegetation. It is **oviparous, carnivorous** and feeds on frogs, rats, lizards and other snakes. It **hibernates**. Three varieties of cobras are found in India : (1) **Binocellate** form having spectacle-like mark connected by U, found in Maharashtra. (2) **Monocellate**—single oval mark surrounded by ellipses found in Bengal. (3) **Non-cellate**—without mark found in Rajasthan, Gujarat and Madhya Pradesh.

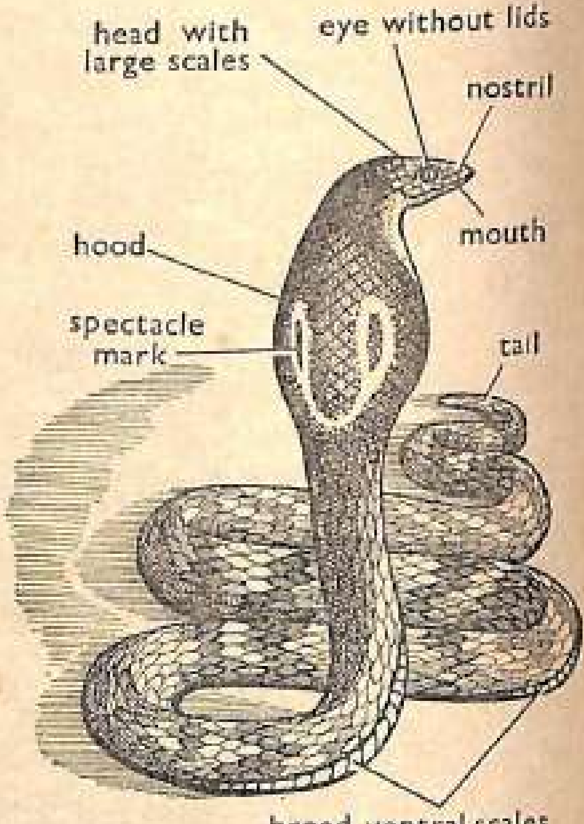


Fig. 3-103. *Naja*.

Comments :

(1) *Naja* is commonly known as **cobra**. *Naja naja* is Indian cobra.

(2) Body measures 2–3 meters in length and is **brownish** in colour (Gehuwa). During hibernation the colour becomes golden but on exposure to light the colour changes to brown.

(3) The **head** is not well differentiated from the neck.

(4) The **neck region** is dilatable and ribs are elongated. The neck region expands and forms **hood**, which contains **binocellate** mark on dorsal surface. Some persons call it spectacle or the figure of ten. There is a white band around mark.

(5) The third shield of the upper **labia** or **lip** large and extending from the **ocular** to the **nasal** shield. The ocular shield bears eye and nasal shield bears opening of nostril.

(6) A tiny **wedge-shield** present between the 4th and 5th lower labials.

(7) **Tail shield** on the undersurface of the tail double.

(8) **Vertebrals** or scales on the mid-dorsal line larger than others and **hexagonal**.

(9) Body is covered by smooth oblique scales.

(10) **Maxillary bone** extends beyond **palatine**. **Poison fangs** are followed by 1–3 small teeth. **Loreal** absent. **Nostrils** large and vertically elliptical. **Frontal** shield truncated.

(11) Eyes with narrow pupils.

Special feature—Cobras are deadly **poisonous** snakes. They raise their **hood** when alarmed and the hood sways back and forth for striking the object. During this period it produces **hissing sound**. It will not strike if intruder become standstill. The snake-bite cases should be immediately attended by medical persons. The snake (*Naja naja*) is very common in India. It is worshipped on Nagpanchami day. The cobra bite is cured sometimes in villages by snake charmers by Mantra or sometimes by sucking poison out of the wound. The presence of a jewel in the head is not correct.

Identification—*By the hood and its mark.*

102. Viper

Classification :

Phylum............**Chordata**
Subphylum.......**Vertebrata**
Superclass.......**Gnathostomata**
Class..............**Reptilia**
Subclass..........**Diapsida**
Order..............**Squamata**
Suborder.........**Ophidia**
} Characters same as those of *Naja*.

Family............**Viperidae**
Type..............*Vipera ruselli* (Kadar).

Geographical distribution—*Vipers* are Old World snakes except Madagascar. *Viper* has been reported from Europe, Asia, Sri Lanka, Burma and India.

Habit and habitat—*Viper* is found in rocky and bushy regions. It feeds on mice, rats, lizards and birds.

Comments :

(1) *Viper* is commonly called in Hindi as **Kadar** or **Dobia**.

(2) *Vipera ruselli* is also a common **poisonous snake** and is often called as **pitless viper**.

(3) Body measures 2 meters in length. **Head** is large, flat, triangular and covered with small scales. A 'V' mark placed overhead. **Shields** on the under surface of the tail subdivided.

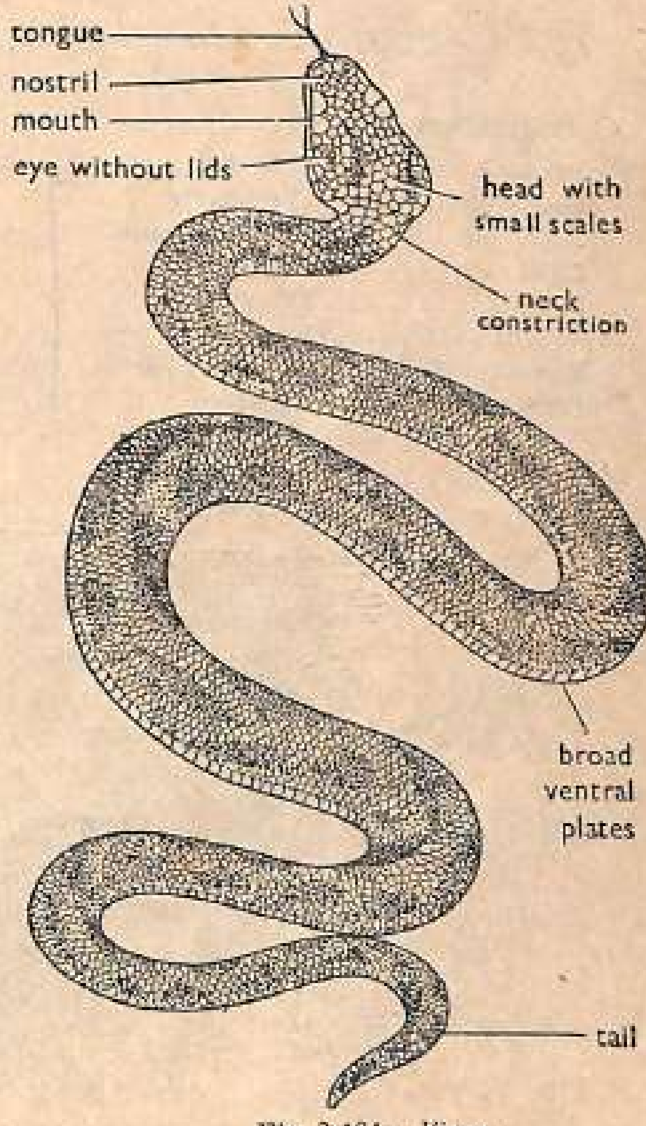


Fig. 3-104. *Viper*.

(4) The colour is brownish but it varies according to its environment. Body is covered with **keeled scales.** Large black spots arranged on the back.

(5) **Facial** bones movable, **maxilla** is small and contains long and movable poison fangs with canals.

(6) **Paired erectile fangs** in front of upper jaw, one on each maxillary bone and folded backwards when not in use (**solenoglypha**).

(7) **Maxillaries** short, thick and movable in vertical plane.

(8) No **pit** between nostril and eye.

(9) **Supra-labials** are 10–12. 4th supra-labial is largest and it does not reach eye. **Ventral plates** large.

(10) **Snout** is **angulate, nasal** opening prominent and largest and **eyes** have white margin with golden iris and **elliptical pupil**.

Special feature—The snake remains coiled with the head in the centre of the coil and with least provocation or disturbance, tongue is protruded, body rhythmically swells and **hissing** sound is produced. Its bite is fierce and it strikes to one side with a sudden and forceful spring. Before striking it **hisses** loudly. Its bite is fatal to man.

Identification—*By ventral plates.*

103. *Ancistrodon himalayanus* or *Argistrodon himalayanus* (Pit Viper)

Classification :

Phylum.....................	**Chordata**	Characters same as those of *Viper*.
Subphylum..................	**Vertebrata**	
Superclass.................	**Gnathostomata**	
Class......................	**Reptilia**	
Subclass...................	**Diapsida**	
Order......................	**Squamata**	
Suborder...................	**Ophidia**	
Family.....................	**Viperidae**	
Type.......................	*Ancistrodon.*	

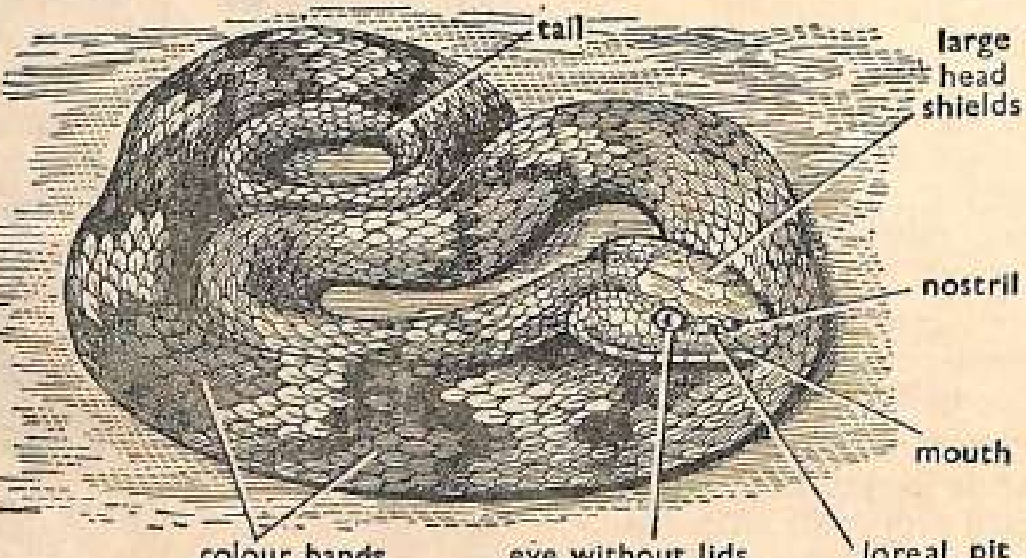


Fig. 3-105. *Ancistrodon* (Pit viper).

Geographical distribution—*Ancistrodon* is found in hilly regions in the north and eastern parts of India and Asia.

Comments :

(1) *Ancistrodon* is commonly called as **Himalayan pit viper.**

(2) A pit-like depression on each side of the upper jaw between nostril and eye.

(3) Body is not much elongated, measures about 1 meter in length.

(4) The colour is bluish brown with dark brown or black spots which appear like **cross-bars.**

(5) **Upper lip** is slightly raised in rostral region, **post-ocular** two, **supra-ocular** enlarged sideways to form shield over the eye, **pre-ocular** three.

(6) **Eyes** are big with golden iris and **vertical** pupil.

(7) **Head** contains loreal pit separating eye and nostril between two pre-oculars.

Special feature—*Pit viper* is a shy and alert snake. Even on slight disturbance it runs back to shelter. It is a **poisonous** snake having well-developed, erectile poisonous and sheathed fangs. It is viviparous.

Identification—*By loreal pit.*

104. *Crocodilus*

Classification :

Phylum.........**Chordata**
Subphylum.....**Vertebrata**
Superclass.....**Gnathostomata**
Class.............**Reptilia**
Subclass.........**Diapsida**
} Characters same as those of *Anistrodon*.

Order...........**Crocodilia** → Body long, head large, jaws powerful, skin thick and leathery, tongue non-protrusible, 4-chambered and reported from rivers and lakes.

Family..........**Crocodilidae**
Type.............*Crocodilus* (Magarmach).

Geographical distribution—*Crocodilus* is found in Southern Asia, Africa, Australia, Central America and India. **Triassic** to **Recent.**

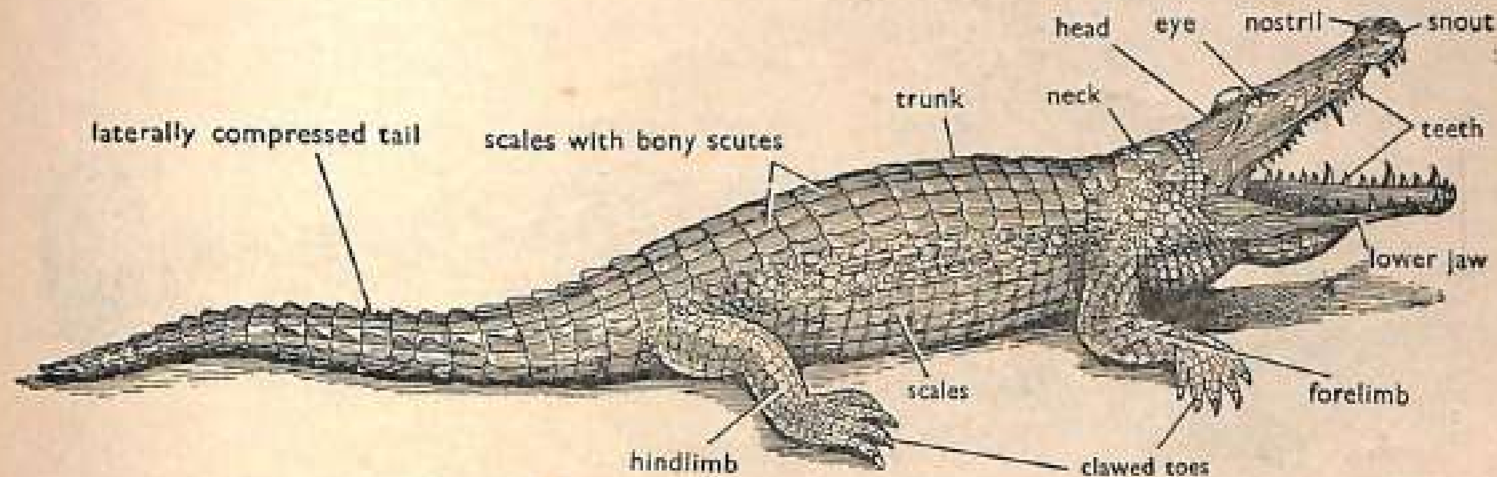


Fig. 3-106. *Crocodilus* (Crocodile).

Habit and habitat—*Crocodilus* is found in rivers and lakes. The animal makes 10–13 meters long tunnel below the level of water. The opening of the tunnel is used as entrance and the other side is used to deposit the eggs.

Comments :

(1) *Crocodilus* is commonly known as **Muggar**.

(2) Body is very much elongated, measuring about 4–6 meters in length.

(3) It is covered by leathery armour, consisting of **osteoscutes** arranged transversely in rows.

(4) Head large, jaws long, powerful, rimmed with numerous bluntly conical teeth.

(5) **Fore** and **hind limbs** short and ending in clawed toes with webs between.

(6) **Tail** long, heavy and compressed.

(7) Ear opening small and protected by a small flap of skin.

(8) **Tongue** not protrusible.

(9) Heart 4-chambered with separate ventricles. **Bladder** absent.

(10) Body is differentiated into head, trunk and tail. Head is long and triangular and narrows towards snout which is not differentiated from the rest of the skull. Teeth are unequal, dental formula 16–19/14–15. The first tooth fits into a pit and fifth mandibular tooth into a notch on the outer side of upper jaw.

Special feature—Crocodile is dangerous to mankind. It can eat the man.

Identification—*By long and pointed snout.*

105. *Alligator*

Classification :

Phylum............**Chordata**
Subphylum........**Vertebrata**
Superclass........**Gnathostomata**
Class..............**Reptilia**
Subclass..........**Diapsida**
Order..............**Crocodilia**
Family.............**Crocodilidae**

Characters same as those of *Crocodilus*.

Type.................*Alligator*.

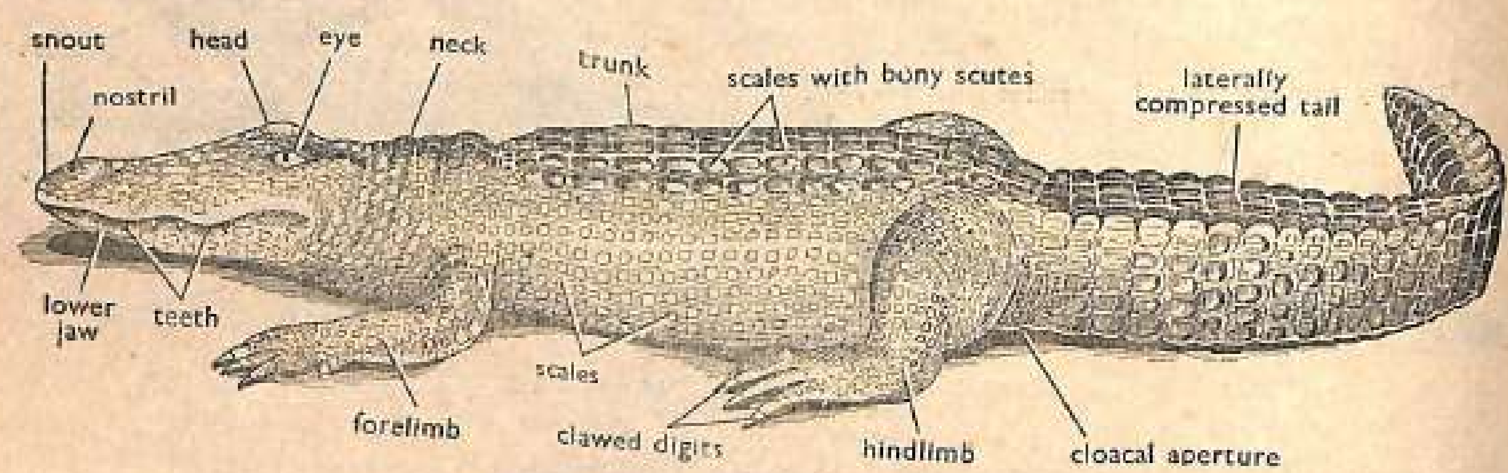


Fig. 3-107. Alligator (*Alligator mississippense*).

Geographical distribution—*Alligator* is found in China and North America.

Habit and habitat—*Alligator* commonly inhabits shallow water and on slight disturbance burries in the sand.

Comments :

(1) Alligator resembles superficially with *Crocodilus.*

(2) Body measures 3-4 meters in length.

(3) Head is broad and snout is bluntly rounded. **Teeth** 17–20/17–22 on each side. The **first** and **fourth mandibular** teeth fit into the pits of upper jaw.

(4) Head large, jaws long, powerful, rimmed with numerous **bluntly** pointed conical teeth which are **very unequal.**

(5) Fore and hind limbs short, pentadactyl and ending in toes with webs between.

(6) Tail long, heavy compressed. (7) Small **ear opening** is protected by a flap of skin.

(8) **Tongue** not protrusible. **Heart** 4-chambered with separate **ventricles**. Bladder absent.

(9) Nasal bones divide nasal aperture. (10) Eggs are laid in nests.

(11) **Body** is covered with thick **leathery skin** containing **scutes.** The dorsal bony scutes do not articulate with each other. The **ventral** scutes are with or without very little ossification. **Mandibular symphysis** is short extending only to the level of 4th and 5th tooth. In water eyes and nostril are exposed.

106. *Gavialis*

Classification :

Phylum............**Chordata**		Characters same as those of *Alligator*.
Subphylum........**Vertebrata**		
Superclass........**Gnathostomata**		
Class...............**Reptilia**		
Subclass...........**Diapsida**		
Order...............**Crocodilia**		
Family.............**Crocodilidae**		
Type...............*Gavialis* (Ghariyal).		

Geographical distribution—*Gavialis* is found in India in Ganges river, Burma and Malaysia. Indian species is *G. gangeticus*. **Upper Cretaceous** to present day.

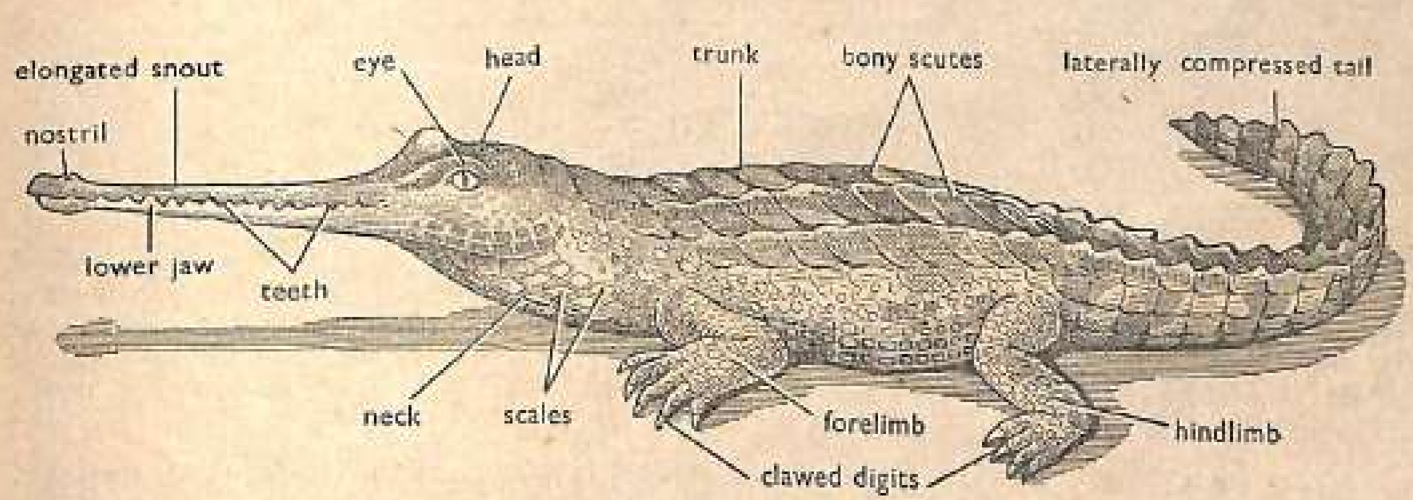


Fig. 3-108. *Gavialis gangeticus.*

Habit and habitat—*Gavialis* lives in Ganges river. It eats fishes.

Comments :

(1) *Gavialis gangeticus* is commonly known as **Ghariyal** or **Naka**.

(2) It is the largest of all crocodilians and is **not dangerous** to mankind.

(3) The **head** is produced into a **long** and **narrow snout** which is sharply distinct from rest of the skull.

(4) Head is large, jaws powerful, rimmed with various conical teeth. **Teeth** sub-equal and **internal nares** within the pterygoids.

(5) Fore and hind limbs short and ending in clawed toes with webs between.

(6) **Tongue** is not protrusible. (7) Heart 4-chambered with separate ventricles.

(8) Bladder absent.

(9) The **tail** is strong and powerful and laterally compressed, containing vertical scutes.

(10) A flap of skin covers the ears.

Identification—*By short snout.*

DISTINCTION OF CROCODILUS, ALLIGATOR & GAVIALIS

The following table gives distinguishing characters of *Crocodilus*, *Alligator* and *Gavialis*.

Characters	Crocodilus	Alligator	Gavialis
(1) Length.	5 meters.	3 meters.	5 meters.
(2) Colour.	Dorsal side olive green with black spots or bands.	Steel grey.	Dark olive green.
(3) Snout.	Long and pointed.	Short but broad.	Elongated.
(4) First and fourth mandibular teeth of lower jaw.	Fit into a pit and groove of upper jaw respectively.	Fit into pits of upper jaw.	Fit into grooves of upper jaw.
(5) The lower jaw rami.	Do not unite beyond 8th tooth.	Do not meet beyond 5th tooth.	Unite upto 14th tooth.
(6) Teeth.	Unequal.	Very unequal.	Sub-equal.

H. MUSEUM SPECIMENS OF BIRDS

NATURAL HISTORY

Birds are the best known and most easily recognized of all animals. Birds have mixed with mankind in every aspect of life. They are unique in having feathers that clothe and insulate their bodies to make possible a regulated body temperature. They have easily avoided all kinds of enemies on land by adapting aerial mode of life. The distinctive colouration and voices of birds appeal to human eyes and ears. Many birds are of economic importance because of their food habits. Certain kinds are hunted as game and few domesticated species contribute to man's food.

Birds represent significant advance over all lower vertebrates in having (a) an insulated body covering, (b) complete separation of venous and arterial circulation in the heart, (c) regulated body temperature, (d) high metabolic rate, (e) highly developed voice, sight and hearing, and (f) the ability to fly.

Birds occupy all continents, oceans and islands, penetrating the Arctic beyond 80°N and the Antarctic, and live from sea level to above timber line on the Everest. They fully obey the laws of animal distribution. Albatrosses live in open ocean, ducks on marshy places, savanna sparrows live on grasses, woodpeckers and others live on trees and so on. In polar regions only few species are found. In temperate lands 150 to 200 kinds of birds may be found in localities at various seasons. Birds have well adapted migratory habits. They fly thousands of miles for breeding and nesting. Primitive people used wild birds for food and garments. Ducks, herons and other birds have been used as game. Feathers of birds provide ornaments to modern women and are also used in sports material.

Outline Classification of Birds

Phylum.........**Chordata**
Subphylum......**Vertebrata**
Superclass......**Gnathostomata**
Class..........**Aves (Birds)**
(a) *Subclass*........**Archaeornithes** *e.g. Archaeopteryx, Archaeornis.*
(b) *Subclass*........**Neornithes**
Superorder I—**Odontognathae** *e.g. Hesperornis, Ichthyornis.*
Superorder II—**Palaeognathae or Ratitae**
- *Order...1*—**Struthioniformes** *e.g. Struthio* (Ostrich).
- *Order...2*—**Casuariformes** *e.g. Casuaris, Dromiceiuse.*
- *Order...3*—**Aepyornithiformes** *e.g. Aepyornis.*
- *Order...4*—**Dinornithiformes** *e.g. Dinornis.*
- *Order...5*—**Apterygiformes** *e.g. Apteryx.*
- *Order...6*—**Rheiformes** *e.g. Rhea.*
- *Order...7*—**Tinamiformes** *e.g. Tinamus, Rhynchotus.*

Superorder III—**Neognothoe or Corinoto**
- *Order...1*—**Sphenisciformes or Impennae.** Penguins *e.g. Aptenodyles spheniscus.*
- *Order...2*—**Gaviiformes** *e.g. Gavia immer.*
- *Order...3*—**Podicipitiformes** *e.g. Podiceps, Podylymbus.*
- *Order...4*—**Procellariiformes** *e.g. Diomedea, Oceanodroma.*
- *Order...5*—**Peleconiformes** Pelicans, *e.g. Pelecanus, Phalacrocorax, Sula* and *Morus.*
- *Order...6*—**Ciconiiformes** Herons, Storks *e.g. Ardea, Butorides, Egretta ciconia, Casmerodius* and *Phoenicopterus.*
- *Order...7*—**Anseriformes**—Ducks, Geese, Swans, *e.g. Anas, Anser, Cygnus, Aythya* and *Brent.*
- *Order...8*—**Falconiformes**—Vultures, Kites, Hawks, Falcons and Eagles; *e.g. Cathartes auria, Coragyps, Gymnogyps, Neophron Porenopterus, Milvus.*
- *Order...9*—**Galliformes**—Grouse, Quail, Pheasants and Turkeys, *e.g. Gallus, Lagopus, Opisthocomus, Francolinus Centropus, Pavo.*
- *Order..10*—**Gruiformes**—Cranes, Rails and Coots, *e.g. Rallus, Fulica, Gallinula, Porphyrio, Antigone* and *Anthropoides.*
- *Order..11*—**Diatrymiformes**—Wingless, *e.g. Diatryma.*
- *Order..12*—**Charadriiformes**—Shore birds, Waders, *e.g. Philohela, Erolia, Capella larus, Brochypternus.*
- *Order..13*—**Columbiformes**—Pigeons and Doves, *e.g. Columba, Ectopistes* and *Zenaidura, Crocopus* and *Streptopelia.*
- *Order..14*—**Cuculiformes**—Cuckoos, *e.g. Coccyzus, Cuculus, Eudynamis, Hierococez.*
- *Order..15*—**Psittaciformes**—Parrots *e.g. Psittacula, Rhynchopsitta.*
- *Order..16*—**Strigiformes**—Owls *e.g. Tylo alba, Bubo bubo, Otus aeio* and *Nyctea scandiaca.*
- *Order..17*—**Caprimulgiformes** *e.g. Antrostomus, Phalaenoptilus.*
- *Order..18*—**Apodiformes**—Swifts and Humming birds *e.g. Chaetura, Pelagica, Archilochus, Micropus.*
- *Order..19*—**Coliiformes**—Mouse birds, *e.g. Colius.*
- *Order..20*—**Trogoniformes**—Trogons, *e.g. Trogon.*
- *Order..21*—**Coraciformes**—Kingfishers, *e.g. Megeceryle, Merops, Halcyon* and *Coracias.*
- *Order..22*—**Piciformes**—Woodpeckers, Barbets, Honey guide, *e.g. Upua epops, Picus.*

Order..23—**Passeriformes**—This order comprises of a large number of birds and contains about 51 families. This order includes cotingas, horned larks, swallows, crows, sparrows, finches, starlings, pipits, blackbirds, wood warblers, tanagers, wax-wings and kinglets. *e.g. Passer domesticus, Malpastes, Kittacinela, Acradotheres, Corvus, Motacilla, Hirundo, Ploceus philippinus, Uroloncha, Corus.*

107. *Phoenicopterus* (Flamingo)

Classification :

Phylum..................	**Chordata**	→ Dorsal tubulated nerve cord, notochord and gill slits present.
Subphylum............	**Vertebrata**	→ Internal skeleton of cartilage or bone, spinal cord forming main axis and composed of overlapping vertebrae.
Superclass............	**Gnathostomata**	→ Jaws and paired appendages present.
Class......................	**Aves**	→ Biped and feathered animals.
Subclass................	**Neornithes**	→ True birds. Metacarpals fused.
Superorder............	**Neognathae**	→ Modern birds, no teeth, sternum keeled.
Order....................	**Ciconiiformes**	→ Long legged and long necked birds.
Type......................	*Phoenicopterus roseus.*	

Geographical distribution—*Phoenicopterus* is found in India, Pakistan and Sri Lanka. It is tropical and subtropical. **Eocene to Recent.**

Habit and habitat—*Phoenicopterus* is found in flocks on shallow jheels, and tidal mudflats, ponds and lakes. The flocks consist of many hundreds of individuals. The birds wade into shallow water and feed with their heads immersed. They feed on small molluscs, crustaceans, insect larvae, worms, seeds of marshes and organic ooze.

Comments :

(1) *Phoenicopterus* is commonly called as Flamingo and **Bog Hans** in Hindi.

(2) It is a **pale, rosy-white bird** with **elongated pink legs** and long **sinuous** neck. It stands one meter high.

(3) **Wing** coverts and wing **borders** are beautiful.

(4) The bill is abruptly decurved in the middle.

(5) It flies rapidly.

(6) The fleshy tongue works like plunger.

(7) Web present between the toes.

(8) It can swim in water.

(9) Head contains eyes.

(10) Many nests are formed in colonies on the tree. Eggs are unspotted.

Fig. 3-109. Flamingo.

Special feature—When at rest flamingos usually stand on one leg with the long neck coiled around and the head tucked away under the feathers of the back. The Raj Hans or Bog Hans is famous for its beautiful, majestic and gracious walk.

108. *Gypus bengalensis*

Classification :

Phylum................	Chordata	Characters same as those of *Phoenicopters*.
Subphylum............	Vertebrata	
Superclass............	Gnathostomata	
Class....................	Aves	
Subclass................	Neornithes	
Superorder............	Neognathae	
Order....................	Falconiformes	→ Feet grasping and bill tearing types.
Type......................	*Gypus bengalensis*	

Geographical distribution—*Gypus* has cosmopolitan distribution. **Eocene to Recent.**

Habit and habitat—*Gypus* is found throughout India in all types of places except humid forests. It lives singly or in gatherings or rabbles. It feeds on a variety of animals.

Comments :

(1) *Gypus* is commonly called as white backed or Bengal vulture. In Hindi it is called as **Gidh.**

Fig. 3-110. *Gypus bengalensis*.

(2) It is dirty, blackish brown and repulsive-looking bird, but very graceful and majestic when **soaring** and circling high up in the sky.

(3) Head is naked and contains large eyes. (4) Back is white.

(5) Bill stout, hooked at the tip with soft naked cere at its base.

(6) Mandibles sharp edged.

(7) Feet usually adapted for grasping with sharp claws. (8) Flight strong.

(9) Vultures nest in large trees near the road or village sides.

Special feature—Vultures are famous for their keen sight and they are of greatest usefulness to mankind as scavengers. Whenever their keen eyes detect a carcase, a large number of these birds collect from all sides and dispose off the flesh of the dead animal within a short period. It is difficult to drive them away. They make peculiar voice while in gathering.

109. *Pavo cristatus*

Classification :

Phylum............**Chordata**		
Subphylum.........**Vertebrata**		
Superclass.........**Gnathostomata**		
Class..................**Aves**	}	Characters same as those of *Gypus*.
Subclass............**Neornithes**		
Superorder........**Neognathae**		
Order.................**Galliformes**	→	Feet adapted for running and scratching.
Type...................*Pavo cristatus*.		

Geographical distribution—*Pavo cristatus* is found in various localities of India. **Eocene to Recent.**

Habit and habitat—*Pavo cristatus* inhabits dense scrub, jungle and forest well provided with rivers and streams. They are shy birds. They feed on grains and vegetable shoots and often do severe harm to newly sown seeds. They also eat small reptiles and insects.

Comments :

(1) *Pavo cristatus* is commonly called as **pea-fowl** or **peacock**. In Hindi it is called as *Mor* or *Mayur*.

(2) It is the **national bird** of India.

(3) Both domesticated and wild birds are common.

(4) The upper **tail coverts** are abnormally elongated which are ornamented with gorgeous **ocellated** or "eyed" **cocks.**

(5) The **head** is crested like cock. (6) The **neck** has green metallic colour.

(7) Bill short. (8) Feathers with aftershafts.

(9) Feet adapted for scratching and running. (10) It makes nests on the ground.

Special feature—The dance of the peacock with its gorgeous tail coverts spread like a fan is very famous. It, dances especially on a cloudy and rainy day. It also produces ugly shrieking sound may-awe in morning, evening, moonlight and on cloudy days.

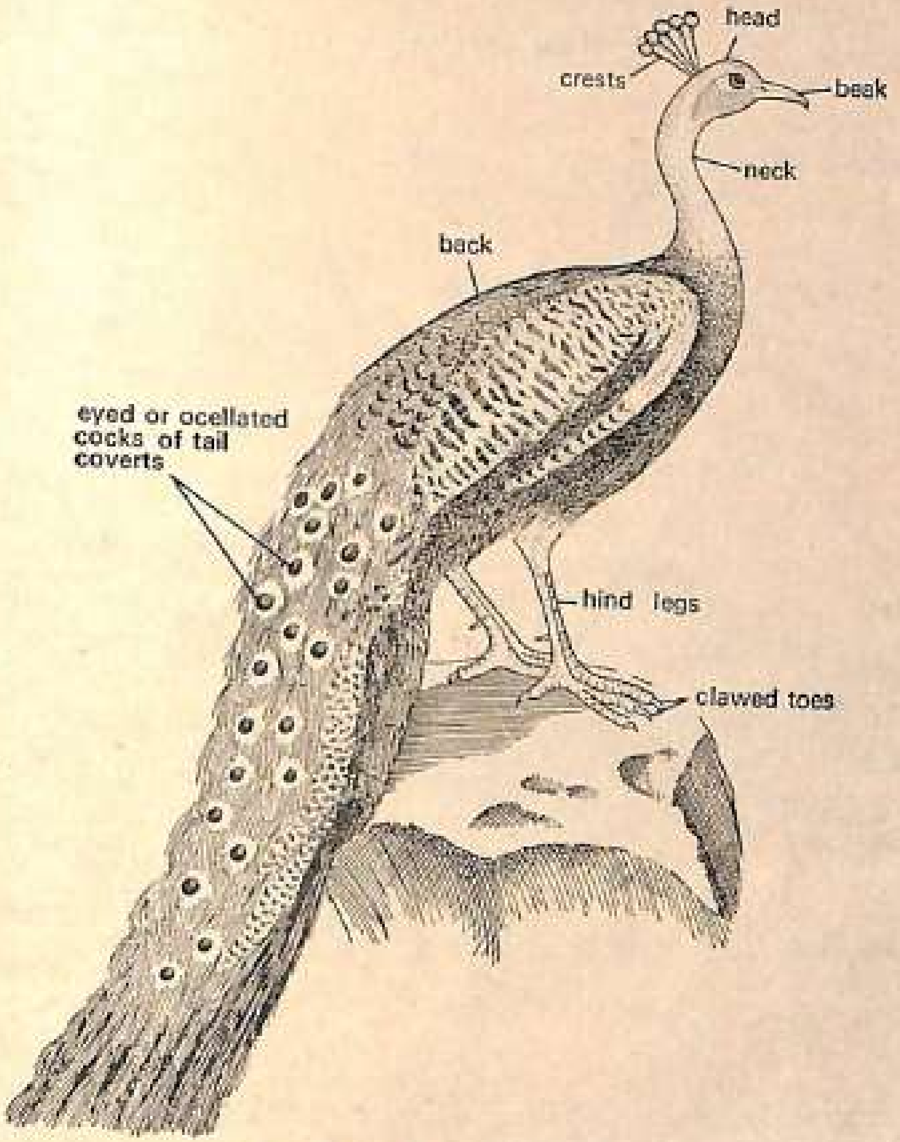


Fig. 3-111. *Pavo cristatus.*

110. *Columba* (Pigeon)

Classification :

Phylum................**Chordata**		
Subphylum..........**Vertebrata**		
Superclass..........**Gnathostomata**		
Class..................**Aves**	→	Warm blooded, bipedal, feathered, forelimbs modified into wings. Four-chambered heart with only right aortic arch and single occipital condyle.
Subclass............**Neornithes**	→	True birds, metacarpals fused, 2nd finger longest, sternum keeled or flat.
Superorder..........**Neognathae**	→	Modern birds, wings well-developed, sternum keeled, pygostyle present.
Order..................**Columbiformes**		
Type...................*Columba livia.*		

Geographical distribution—*Columba* is commonly found in India, forested zone of the Pacific coast and United States. **Eocene** to **Recent**.

Habit and habitat—*Columba livia* is the most common and familiar bird around man, nesting in buildings, old houses, warehouses, sheds and railway stations. Their flight is swift and strong. Breeding continues throughout the year.

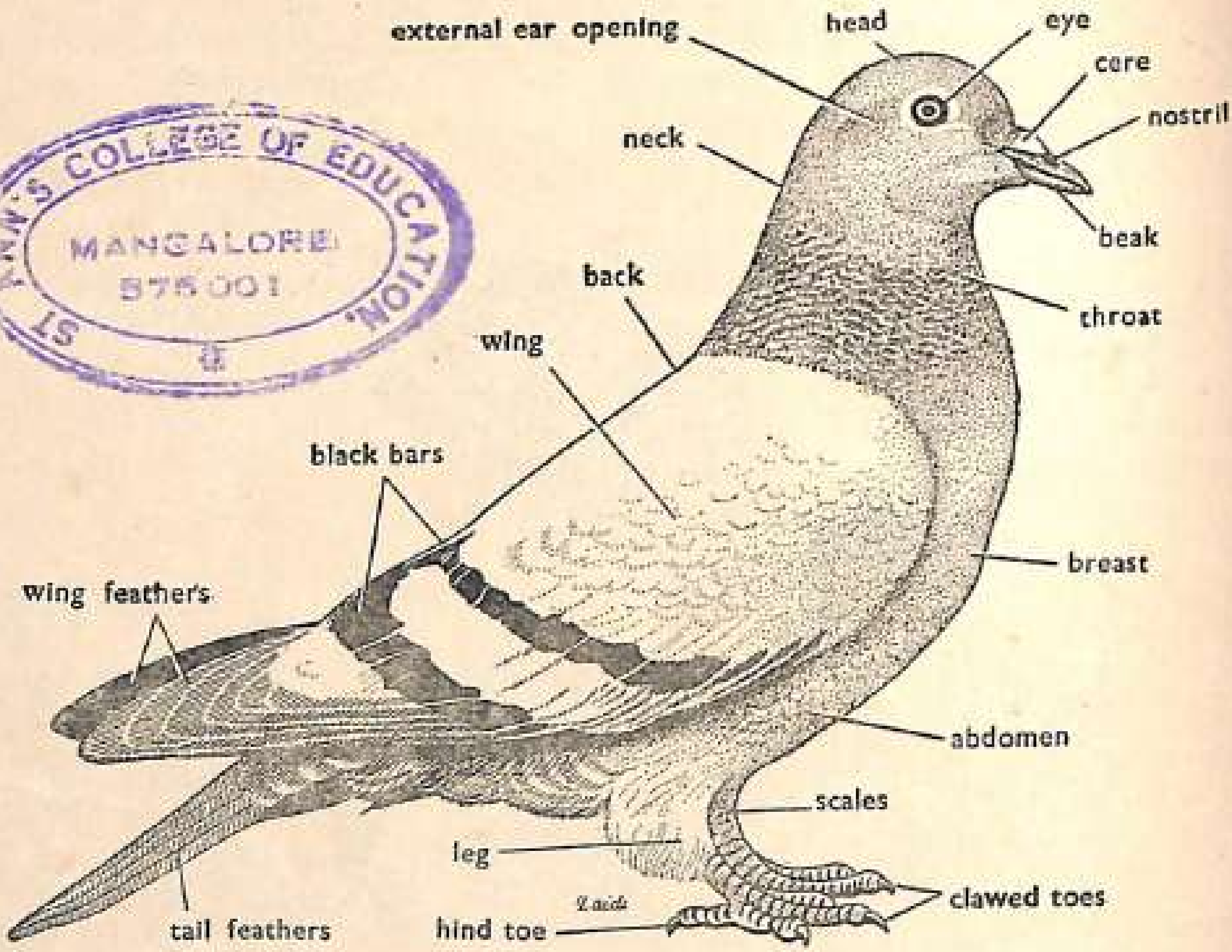


Fig. 3-112. Pigeon (*Columba livia*).

Comments :

(1) *Columba* is commonly called as pigeon and in Hindi **Kabutar.**

(2) Body is divisible into **head, neck, trunk** and **tail.**

(3) The plumage is grey with glistening metallic green and purple on breast and neck. Entire body surface except feet are covered with feathers.

(4) Feet are covered with epidermal scutes formed by the fusion of several reptilian epidermal scales.

(5) Head contains large eyes and slit-like nostrils. It is produced into a short and slender **bill** or **beak.** Upper and lower beaks are covered by a horny sheath, called as **rhamphotheca.** At the base of the upper beak there is a patch of skin called as **cere.**

(6) Eyes are large, rounded with movable **lid**, a well-developed **nictitating** membrane and a rounded **pupil.**

(7) The forelimbs are modified into wings which contain besides skeleton flight feathers called as **remiges.**

(8) After removing feathers animal looks short with long **neck** and a pointed tail called as **uropygium.**

(9) Hind limbs are modified for bipedal locomotion. Tarsus usually shorter than toes.

(10) Crop large, producing **pigeon milk** to feed small young.

(11) Eggs white and unmarked.

Special feature—Pigeons are the most common **domesticated birds**, which were in olden times used as messengers. They are also eaten by man. Their call notes are very familiar to man as *gootr-goon, gootr-goon.* Pigeons serve as an excellent example for artificial selection as various varieties have been produced by man.

111. *Psittacula* (Parrot)

Classification :

Phylum	**Chordata**	Characters same as those of *Columba.*
Subphylum	**Vertebrata**	
Superclass	**Gnathostomata**	
Class	**Aves**	
Subclass	**Neornithes**	
Superorder	**Neognathae**	
Order	**Psittaciformes**	
Type	*Psittacula eupatria.*	

Geographical distribution—*Psittacula eupatria* is found in India, Pakistan, Burma, Sri Lanka and the United States. **Eocene to Recent.**

Habit and habitat—*Psittacula* lives in flocks in the bustling precincts of a city as much as in the countryside. It is commonly found in the fruit trees, ripe crops and in jungles. **Gregarious** with loud voices. Feeds on fruits and crops.

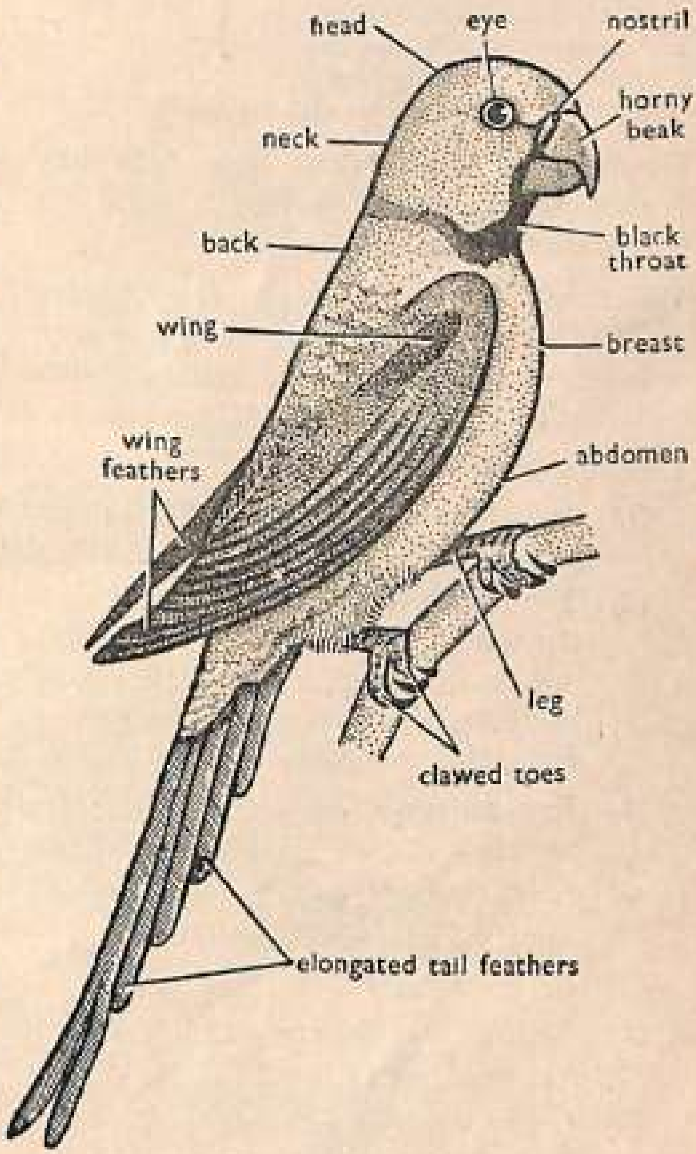


Fig. 3-113. Parrot (*Psittacula eupatria*).

Comments :

(1) *Psittacula eupatria* is commonly called as Indian **parakeet** or parrot and in Hindi it is known as **Hiraman tota.**

(2) It has brilliant **blue-green plumage** with massive, deeply-hooked **red bill** and a distinct maroon patch on shoulder. *P. krameri* has no shoulder patches, while *P. cyanocephala* has a bluish-red head and maroon shoulder patches.

(3) **Beak** stout, narrow, sharp edged and hooked at the tip.

(4) **Upper mandible** movable on the frontal bone of the skull and it is so articulated that its lowering automatically raises the upper beak, which is curved at the tip.

(5) **Feet** adapted for **grasping**, holding and climbing. Foot **zygodactylous** in which I and IV digits are directed backwards, II and III forward to provide a firm grip on the branch of the tree.

(6) Tail feathers elongated. (7) Flight is graceful and voice powerful.

(8) The male rose-pink and black coloured. (9) Nesting season December to April.

Special feature—Parrot is a popular **domesticated** cage bird, found almost in every home and it copies and speaks some words like man. It is a serious **agricultural** pest to the cultivators and food growers. It causes enormous harm to standing crops and ripening orchard fruits. Its voice is sharp, well familiar and screaming *kee-ak*, *kee-ak*, *kee-ak*, *kee-ak*.

112. *Bubo bubo*

Classification :

Phylum............**Chordata**
Subphylum........**Vertebrata**
Superclass........**Gnathostomata**
Class...............**Aves**
Subclass...........**Neornithes**
Superorder........**Neognathae**
} Characters same as those of *Columba*.
Order.............**Strigiformes**
Type................*Bubo bubo* (Linnaeus).

Geographical distribution—*Bubo bubo* has world-wide distribution, specially found in India, Pakistan and Burma.

Habit and habitat—*Bubo bubo* is a nocturnal bird, living in woody places and avoids heavy forests. It feeds on small mammals, rodents, birds, lizards and other animals. It hides in retreat in day.

Fig. 3-114. Horned owl (*Bubo bubo*).

Comments :

(1) *Bubo bubo* is commonly called as great **horned owl** and in Hindi it is known as **Ghughu.**

(2) The underpart is pale with dark and vertical streaks. It is a large, heavy and dark brown **owl, mottled** and striped with small buff and black. **Feather tufts** are projecting above head, like long ears.

(3) **Eyes** are large, yellow and forwardly directed, each in a disk of radial feathers.

(4) **Ear** opening large, often with flap-like cover, sometimes asymmetrical.

(5) **Beak** short.

(6) **Feet** adapted for grasping; claws sharp.

(7) **Plumage** soft textured and lax.

(8) **Legs** are fully feathered.

(9) Nesting season November to April.

Special feature—*Bubo bubo* is of great economic value to mankind by destroying the harmful animals like rats and mice and these birds need careful protection. Soon after sunset, they produce deep soothing prolonged voice *bu-bo*.

113. *Eudynamus scolopacea*

Classification :

Phylum..............**Chordata**
Subphylum.........**Vertebrata**
Superclass..........**Gnathostomata**
Class.................**Aves**
Subclass.............**Neorinthes**
Superorder..........**Neognathae**

} Characters same as those of *Bubo bubo*.

Order................**Cuculiformes** → Feet with two toes in front and two behind.
Type..................*Eudynamus scolopacea*.

Geographical distribution—*Eudynamus scolopacea* is commonly found in India.

Habit and habitat—*Eudynamus* lives on trees of gardens, groves, large leafy trees and their frequent voice *kuoo kuoo* is often heard during mango season. It feeds on banyan and peepul figs, berries, and also insects and caterpillars. The bird has the habit of laying its eggs in the nests of crows and throwing on them the responsibility of raising its young. Koel's song has been associated with romantic Hindi poetry.

Comments :

(1) *Eudynamus scolopacea* is commonly called as **Koel.**
(2) It is about the size of the crow.
(3) **Male** is characterized by having glistening metallic black all over with yellowish green bill and blood-red eyes.
(4) **Female** is brown with white spots.
(5) In summer months the call of the male bird is very familiar *kuoo-kuoo-kuoo.* The voice begins with low *kuoo* and finishes abruptly after high 7th or 8th call. Female does not sing.
(6) Toes 2 in front and 2 behind, outer hind toe reversible.
(7) Beak, moderate, pointed and curved downwards at the tip.
(8) Eyes are small with rounded pupil. (9) **Feet** not adapted for grasping.
(10) **Tail** long.

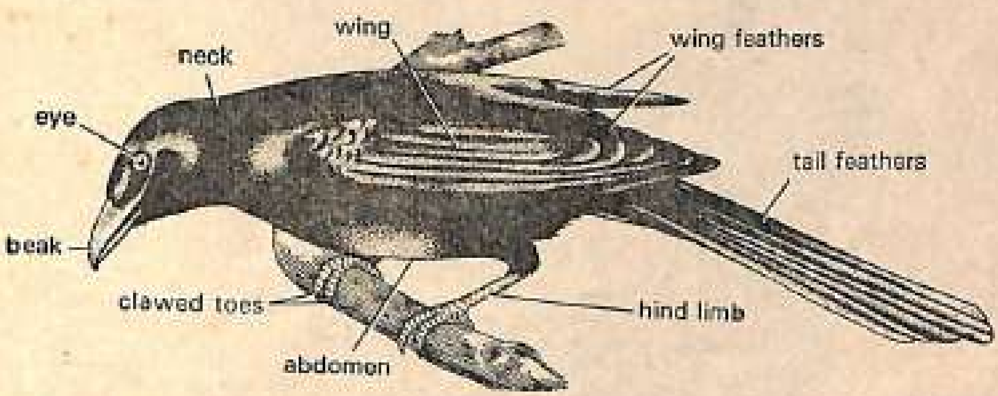


Fig. 3-115. *Eudynamus scolopacea* (Male specimen).

114. *Dendrocopus mahrattensis*

Classification :

Phylum............	**Chordata**	
Subphylum.......	**Vertebrata**	Characters same as those of *Bubo bubo*.
Superclass.......	**Gnathostomata**	
Class................	**Aves**	
Subclass..........	**Neornithes**	
Superorder.......	**Neognathae**	
Order..............	**Piciformes**	
Type...............	*Dendrocopus mahrattensis*.	

Geographical distribution—*Dendrocopus mahrattensis* is widely distributed in Indian subcontinent. **Eocene to Recent.**

Habit and habitat—The woodpecker is a small bird inhabiting light scrub in countryside, thin forests, mango orchards, groves of trees and other leafy trees. They scuttle up tree trunks and branches, tapping on the bark and peer into the cracks for ants and grubs which

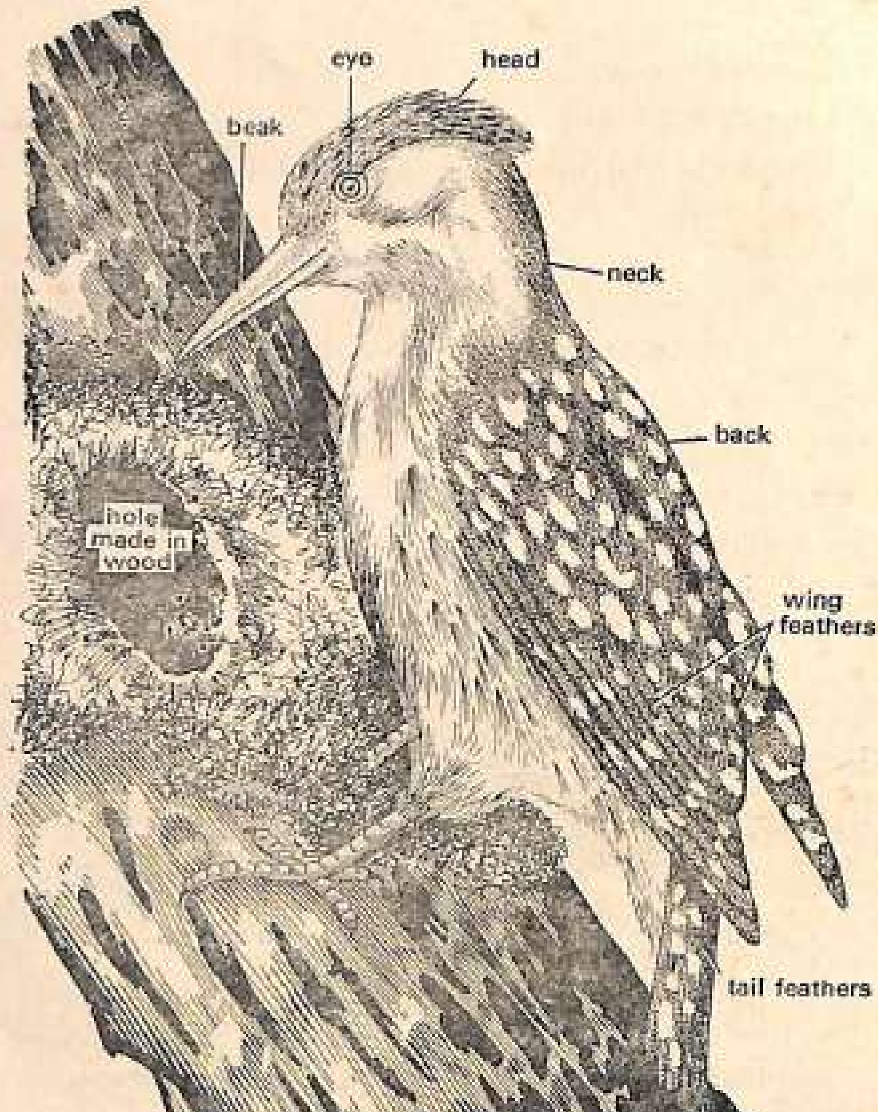


Fig. 3-116. *Dendrocopus maharattensis.*

are extracted by the help of long worm-like tongue. They produce sharp voice *click, click* or *click-r-r-r*. It excavates nest cavities by destroying the wood itself.

Comments :

(1) *Dendrocopus* is commonly called as woodpecker or **Katphorwa** in Hindi.

(2) It has the size of a Bulbul. (3) **Beak** is long, stout and pointed, awl-like.

(4) **Tail** is stiff and wedge shaped. Tail feathers with pointed tips.

(5) Eyes are large. (6) Tongue roughened with barbs near the tip and protrusible.

(7) Toes 2 in front and 2 behind, not reversible.

(8) **Upper plumage** contains black and white spots. (9) Male has scarlet patches.

(10) It makes nest by destroying the wood itself. They live in pairs.

115. *Passer domesticus*

Classification :

Phylum............**Chordata**
Subphylum..........**Vertebrata**
Superclass..........**Gnathostomata**
Class............... **Aves**
Subclass............**Neornithes**
Superorder.........**Neognathea**

(Phylum to Superorder: Characters same as those of *Bubo bubo*.)

Order.................**Passeriformes**
Type............... ..*Passer domesticus* (sparrow).

Geographical distribution—*Passer domesticus* is abundantly found in Sri Lanka, Burma, Pakistan and India. **Eocene** to **Recent.**

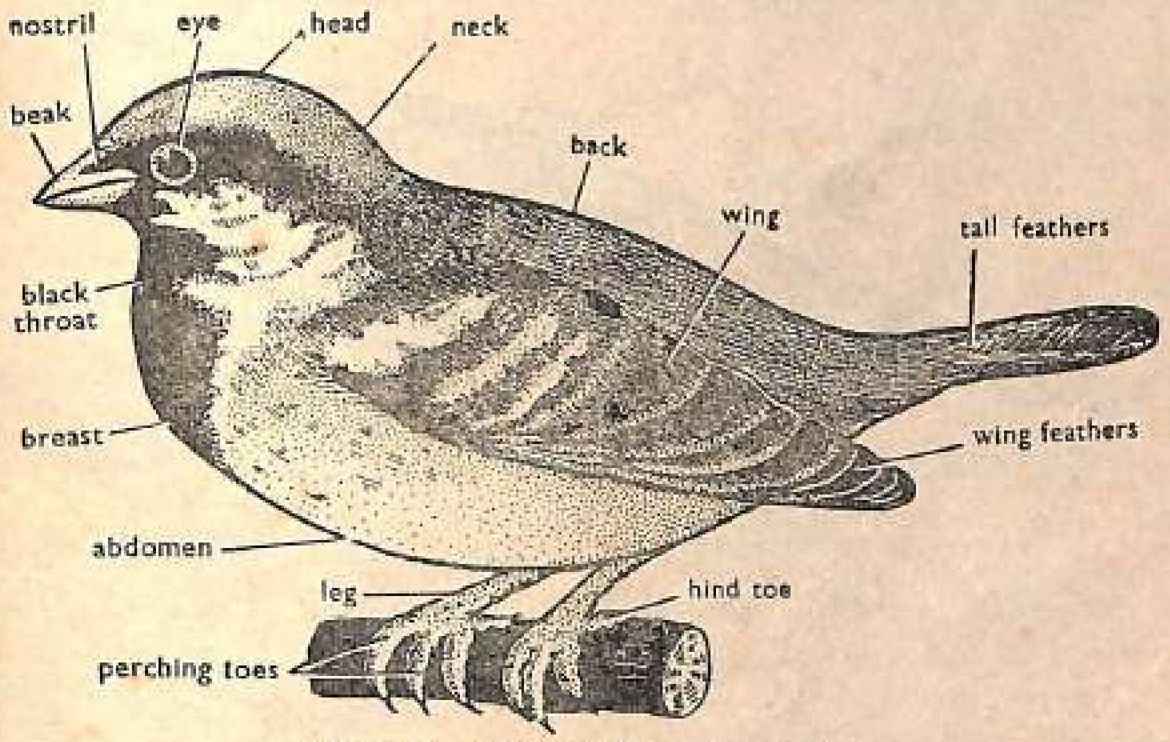


Fig. 3-117. Sparrow (*Passer domesticus*).

Habit and habitat—*Passer domesticus* is the most familiar companion bird of birds in the house. Sparrows freely move and nest in the houses. They act as commensal to man. In winter they feed on cultivated areas in flocks.

Comments :

(1) *Passer domesticus* is commonly called as **house sparrow** and in Hindi as **Gauriyya.**

(2) It is the most common and familiar Indian bird.

(3) The **female** is ashy-grey-brown, measuring about 15 cm. The male is earthy brown with black spots and whitish abdomen.

(4) Eyes small. (5) Beak short and curved. (6) Toes 3 in front and 1 behind.

(7) Feet adapted for perching, neither reversible nor united.

(8) Nesting practically throughout the year. Some make elaborate nests; lay 3–8 eggs.

(9) Young naked and blind at hatching, require feeding and care by parents before becoming independent.

(10) The sparrows are both **useful** and **harmful** to mankind. They destroy several **agricultural pests.** They also **destroy** vegetable and flower buds.

116. *Corvus splendens*

Classification : Same as those of *Passer domesticus.*

Geographical distribution—*Corvus splendens* is found everywhere in India.

Habit and habitat—*Corvus* is the most common, most familiar, most intelligent and boldest bird, living on trees in towns, villages and gardens. It feeds on anything from dead meat to any eatable left on the table i.e. bread, butter, fruits and other preparations.

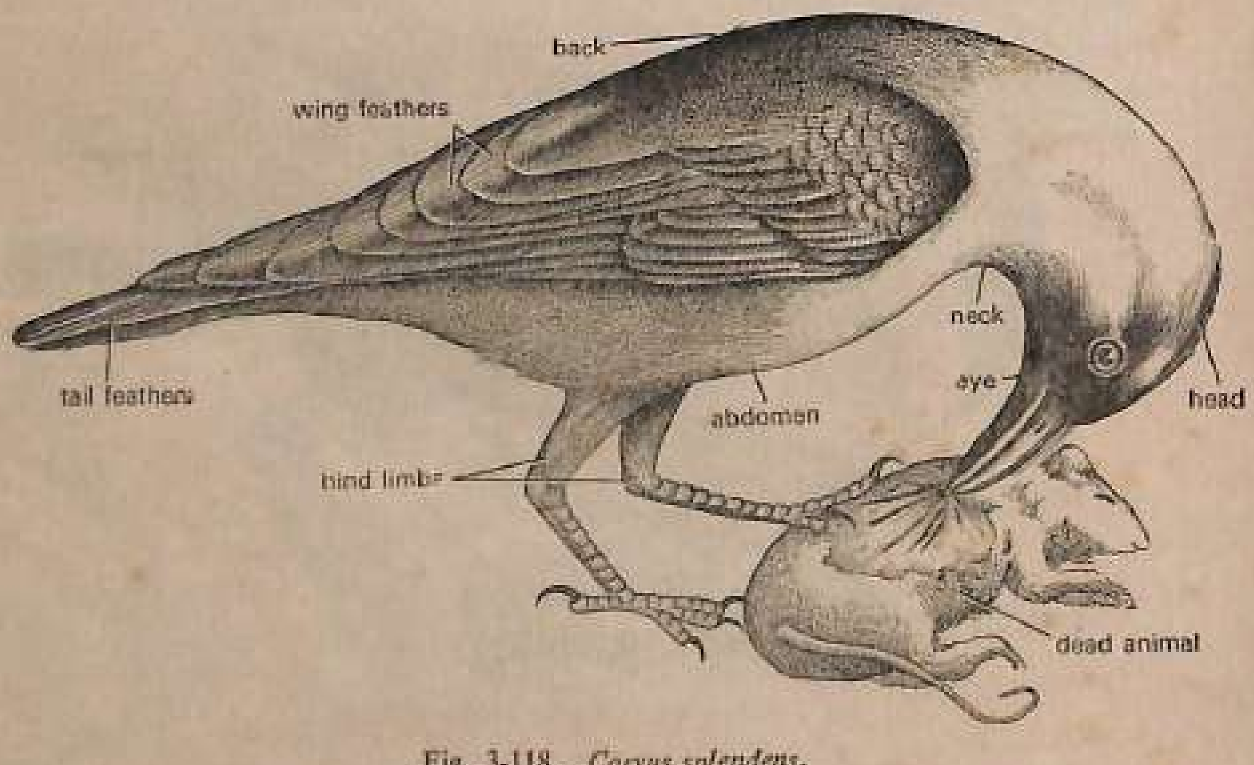


Fig. 3-118. *Corvus splendens.*

Comments :

(1) *Corvus splendens* is commonly called as **house crow** and called as *Kowwa* or *Kag* in Hindi.

(2) The house crow has **grey neck** and black back.

(3) Head raised upwards. (4) It is very intelligent and danger avoiding.

(5) Beak elongated. (6) Toes 3 in front and 1 behind.

(7) Feet adapted for perching. (8) Eyes large. (9) Tail feathers elongated.

(10) Young naked and blind at hatching, require feeding and parental care before becoming independent.

Special feature—The house crow acts as efficient **municipal** scavenger. It destroys locusts and other injurious insects but it also destroys the crop and fruits in orchards. The house crow builds nests of stick. They roost communally in large flocks. They are also a menace to the eggs and infants of other birds. Whenever any fellow crow dies, several crows assemble.

I. TYPES OF BEAKS IN BIRDS

The diversity of form of beaks is mainly related to the type of food eaten and to the manner of feeding. Birds exhibit almost indefinite variations in shape, size and structure of beaks, of which only some of the most important and common types are described here.

1. **Seed-eating beak**—Short, stout, peg-like and conical beaks are characteristic of small grainivorous or seed-eating birds, such as *sparrows, finches* and *cardinals*.
2. **Cutting beak**—Birds, such as *crows*, possess long and slender beaks with cutting edges which can be used variously.
3. **Fruit-eating beak**—In *parrots*, the beak is sharp, massive, deeply hooked and extremely strong. It is well adapted for gnawing or breaking open hard seeds and nuts, which form their staple diet.

   The enormous beak of *hornbills*, looking so heavy and cumbersome, is really quite light as its interior is of a cellular structure. It is suggested that these cells act as resonators, thus enabling the bird to produce its exceptionally loud cry.
4. **Insectivorous beak**—In *swallows* and *swifts*, the beak is small, wide and delicate to scoop up their living insect prey while on wing. In *fly catchers*, the beak is short but strong, with mandibles notched at the tip and beset with numerous rictal bristles at the base.

   In *hoopoe*, the beak is long, slender and slightly curved and meant for turning the leaves or probing into the soil for insect grubs and pupae, etc.
5. **Wood-chiselling beak**—*Woodpeckers* have elongated, straight and stout chisel-like beaks for drilling into the barks or wood for insect larvae or for nest construction.
6. **Tearing and piercing beak**—Carrion-feeding and flesh-eating birds, such as *vultures, hawks, eagles, owls* and *kites* etc., have short, pointed, sharp-edged and powerful, hooked beaks for tearing flesh and operated by well-developed mandibular muscles.
7. **Mud-probing beaks**—Familiar examples of mud-probing beaks are found in *snipe, stilt, sand-piper, Jacana* and *Lapwing*, etc. Their beaks are extremely long and slender and are used as a probe for thrusting far down into water and mud in search of worms and larvae.

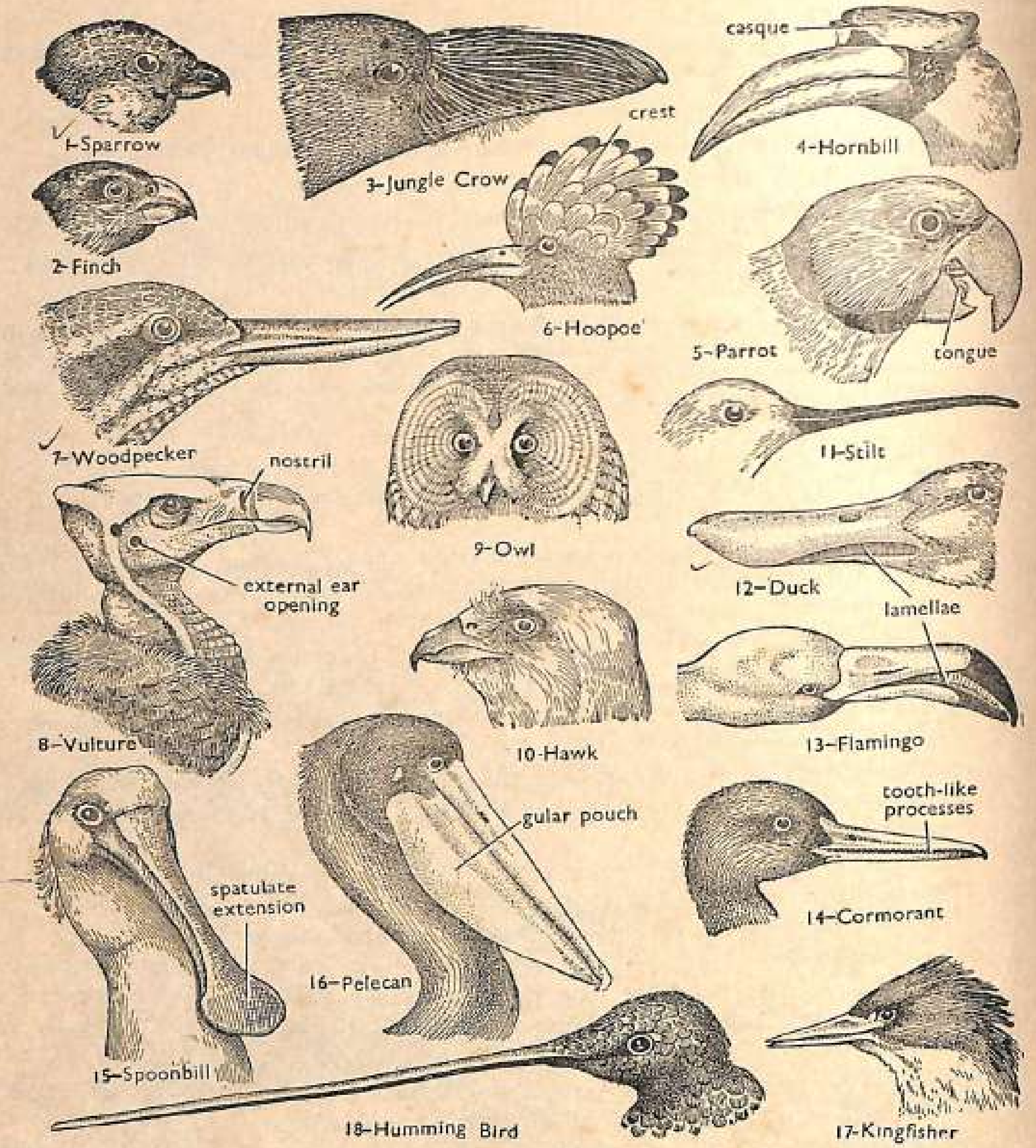


Fig. 3-119. Kinds of beaks in birds.

8. **Water and mud-straining beak**—In *ducks, teals* and *geese*, the beak is broad and flat. The edges of the jaws are furnished with horny serrations or transverse lamellae, which act as a sieve or strainer, letting the water and mud pass out while retaining the food in the mouth.

In *flamingoes*, the beak is distally curved downwards and likewise furnished with shifting lamellae.

9. **Fish-catching beak**—*Storks, herons* and *kingfishers* have long, powerful and sharply-pointed spearing beaks to capture fish, frogs, tadpoles and similar aquatic animals. *Cormorants* have long and narrow beaks, the edges of which are armed with sharp backwardly-directed, tooth-like processes meant for capture of fish. In *snake-birds* or *darters*, these serrations take the form of fine needle-like points.
10. **Spatulate beak**—The *spoon-bill* possesses a very specialized form of beak. It is flattened throughout its length but terminates in a broad, spatulate or spoon-like expansion meant for dabbling in water and mud in search of insects, worms, fish, molluscs and other small animals upon which the bird feeds.
11. **Pouched beak**—*Pelicans* consume enormous quantities of fish. Their beak is large, with a capacious gular pouch of extensile skin attached to the lower mandible and serving as a fishing net.
12. **Flower-probing beak**—The long, pointed and rapier-like probing beak of tropical *humming-birds* dive down the corollas of flowers for sucking honey and insects.

J. TYPES OF FEET OR CLAWS IN BIRDS

The feet of birds are also modified variously in accordance with the character of the environment and the manner of locomotion.

1. **Running feet**—In running birds, the legs are powerful and the number of toes is reduced. The hind toe may be elevated or reduced or absent. In *bustards, coursers* and ratites such as *emu, rhea* and *cassowary*, only 3 toes directed forwards are present. *Ostrich* has only 2 toes, of which the outer one is smaller and without a nail.
2. **Perching feet**—The majority of birds belong to the category of perching birds or *passers*, such as *sparrows, crows, bulbuls, robins, mynahs*, etc. The toes are movable and free, large and provided with sharp and curved claws. Three toes are anterior and slender, while one toe or hallux is posterior, strongly built and apposable, so that they can securely fasten the foot to a branch or any perch.
3. **Scratching feet**—The feet of *fowls, quails* and *pheasants*, etc. are stout, with strongly-developed claws and well adapted for running as well as scratching the earth. The foot of male bird is usually provided with a pointed bony spur for offence and defence.
4. **Raptorial feet**—Predatory or carnivorous birds, such as *eagles, kites, vultures* and *owls*, etc. have strongly taloned feet for striking and grasping their prey. The toes have strongly-developed, sharp and curved claws. Large and fleshy bulbs, called *tylari*, are found on the undersurface of the toes, especially developed in the *sparrow-hawk*. In *osprey* and *Ketupa*, tylari are absent but horny spines are present, which help in gripping slippery preys such as fish.
5. **Wading feet**—The legs and toes are exceptionally long and slender in wading or marshy birds such as *herons, snipes, jacana, lapwing*, etc. These serve to walk over aquatic vegetation or marshes. The web is absent or feebly developed.
6. **Swimming feet**—In swimming birds, the toes are webbed, partially or completely. In diving birds, like *coots* and *grebes*, the web is lobate and the toes are free. In swimming and padding birds, such as *ducks* and *teals*, only the anterior three toes are united in a web. In *pelican* and *cormorant* all the four toes are enclosed in the web.

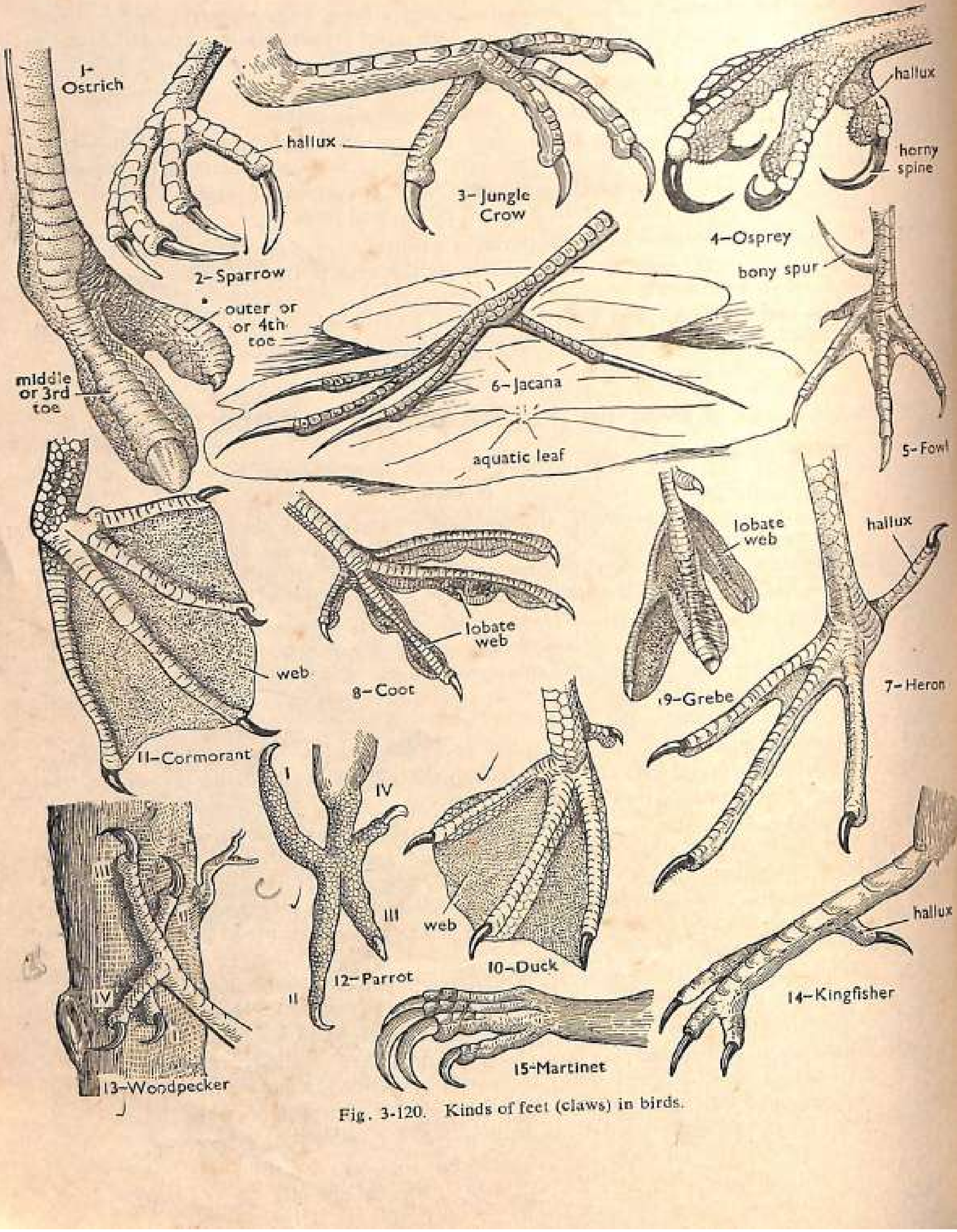


Fig. 3-120. Kinds of feet (claws) in birds.

7. **Climbing feet**—In *parrots* and *woodpeckers* the feet are used as grasping organs and especially adapted for climbing on vertical surfaces. The second and third toes point in front, while the first and the fourth toes point backwards.
8. **Clinging feet**—In *swifts, martinets* and *humming-birds*, all the four toes point forwards and serve to cling to steep faces of cliffs or under eaves of houses, etc.

K. MUSEUM SPECIMENS OF CLASS MAMMALIA

NATURAL HISTORY

Mammals are the highest group in the animal kingdom, comprising moles, bats, rodents, cats, monkeys, whales, horses, deer, elephants and other animals. All are covered with hair or fur and are warm blooded. The term mammal refers to mammary glands on females that supply milk for sucking young. Parental care is highly developed. The insulated body covering and complete separation of venous and arterial blood in the heart make the regulated body temperature possible. High rate of metabolism requires large food. Cerebellum and cerebrum provide high degree of co-ordination in all activities.

Various mammals live in all sorts of habitat from polar regions to the tropics, from sea to densest forests and driest deserts. Mammals inhabit all parts of the earth—land, water and air. The walrus and some seals live in the Arctic seas and ice, whales and porpoises in open sea, musk rat and otter live in fresh water. The grasslands and forests are homes of many rodents, carnivores and hoofed animals. Population density varies with available cover and food. Natural crevices, holes, rocks, holes in trees, burrows, tunnels etc. provide shelter for various mammals. Mammals also form good source of animal products industry, i.e. meat, wool and leather are obtained from them. They also provide transport and recreation.

Outline Classification

Phylum.........**Chordata**
Subphylum....**Vertebrata**
Superclass.....**Gnathostomata**
Class.............**Mammalia**

A. *Subclass*.......**Prototheria**
Order...........**Monotremata** *e.g. Ornithorhynches, Tachyglossus* (Echidna).

B. *Subclass*.......**Theria**
Infraclass I—**Metatheria**
Order...........**Marsupialia**—Pouched mammals, *e.g. Didelphys, Macropus, Perameles.*
Infraclass II—**Eutheria**—Placental mammals.
Order (*1*) **Insectivora**—*e.g. Talpa, Scalopus, Erinaceus, Sorex.*
Order (*2*) **Dermoptera**—Flying lemurs, *e.g. Galeopithecus.*
Order (*3*) **Chiroptera**—Bats.
Suborder (*a*) **Megachiroptera**, *e.g. Pteropus.*
Suborder (*b*) **Microchiroptera**, *e.g. Myolis, Desmodis.*
Order (*4*) **Primates**
Suborder (*a*) **Lemuroidea** *e.g. Lemur, Loris.*
Suborder (*b*) **Tarsioidea** *e.g. Tarsius.*
Suborder (*c*) **Anthropoidea.** New and Old World monkeys and apes, *e.g. Callithrix, Ateles, Macaca, Hylobatus, Simia, Pan, Gorilla* and *Homo sapiens* (Man).
Order (*5*) **Rodentia** *e.g. Funambulus, Mus musculus, Rattus rattus, Castor, Hystrix.*
Order (*6*) **Pholidota**—Scaly an-teaters *e.g. Manis.*
Order (*7*) **Edentates** *e.g. Dasypus, Bradypus, Cholaepus.*
Order (*8*) **Carnivora** *e.g. Felis* (cat), *Panthera* (tigers), *Canis lupus* (wolf), *Vulpes* (fox), *Phoca* (seals), *Herpes tes* (Mongoose), *Lutra.*
Order (*9*) **Proboscidea**—Elephants, *e.g. Elephas, Loxodonta.*
Order (*10*) **Perissodactyla**—Odd-toed ungulates, *e.g. Rhinoceros, Equus.*
Order (*11*) **Artiodactyla**—Even-toed ungulates, *e.g. Sus* (pig), *Hippopotamus, Bos elaphis* (Nilgai), *Bos bubalus* (buffalo), *Bos indian* (cow), *Camelus* (camel), Antelope, *Gir affa* (giraffe).

117. *Ornithorhynchus*

Classification :

Phylum............**Chordata**	}	Characters same as those of *Passer domesticus*.
Subphylum........**Vertebrata**		
Superclass........**Gnathostomata**		
Class...............**Mammalia**	→	Body covered with hairs, skin has several glands, skull with 2 occipital condyles, heart four chambered and females have mammary glands.
Subclass...........**Prototheria**	→	Egg-laying mammals.
Order...............**Monotremata**	→	Egg-laying mammals with coracoid and precoracoid, without pinna, cloaca present and mammary glands without nipples.
Type................*Ornithorhynchus*.		

Geographical distribution—*Ornithorhynchus* is found in South-eastern Australia and Tasmania. **Triassic** to **Recent**.

Habit and habitat—*Ornithorhynchus* is a native of the rivers, pools and creeks. It burrows to 40 feet long in river banks. It feeds on freshwater invertebrates, carried in cheek pouches.

Comments :

(1) *Ornithorhynchus* is commonly called as **duck-billed platypus**.

(2) It measures about 50 cm. in length.

(3) Body is divided into head, thick **trunk** and **tail**.

(4) **Head** is distinct. The upper jaw is produced to form beak or **muzzle-like flattened bill** or **beak** which is covered by skin.

(5) Body is covered with soft brown fur, combining the character of a duck with mammal.

(6) Eyes are small having nictitating membrane.

(7) **Pinna** or external ear absent. (8) **Tail** is flat and adapted for swimming.

(9) **Forelimbs** have 5 digits having digging claws. **Foot** is slightly webbed.

(10) **Coracoid** and precoracoid present, **teeth** only in young.

(11) **Cloaca** present. Ureters open in dorsal wall of urinogenital passage.

(12) **Testes** abdominal, **penis** conducts only sperms. Oviducts distinct, **uterus** or vagina absent and mammary glands without nipples.

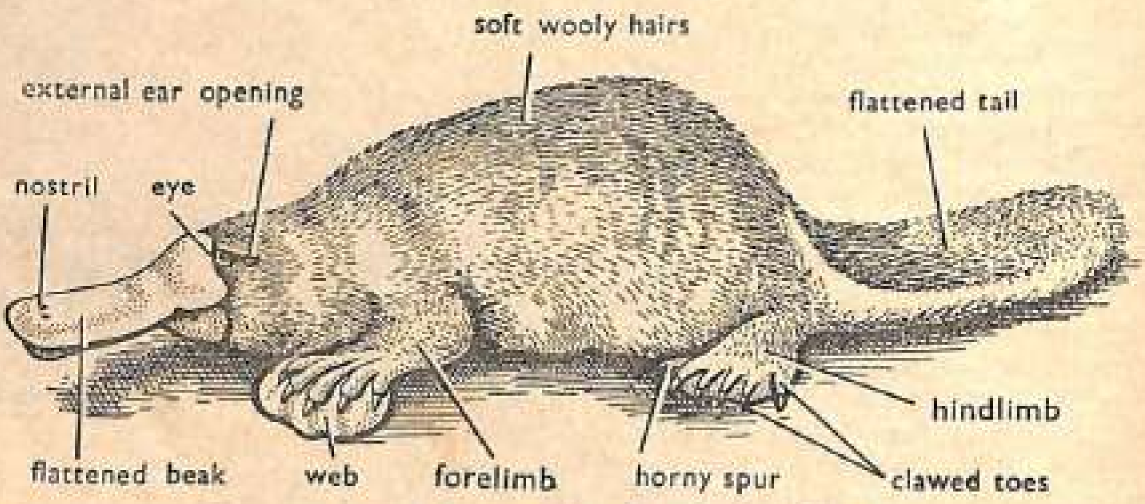


Fig. 3-121. Duck-bill (*Ornithorhynchus*).

(13) Female makes nest of roots and leaves during spring in burrows, lays 1–3 **eggs**. About 5 cm. long young one is hatched which is **nursed** by the **female**. It nurses by lapping up milk secreted by scattered mammary glands on the abdomen of female.

Special feature—*Ornithorhynchus* is an **egg-laying mammal** and exhibits **reptilian**, mammalian and intermediate characters. Reptilian features are urinogenital system, precoracoids, absence of pinna and **corpus collosum**. Mammalian features include hair, diaphragm, **4–chambered heart**, **3-ear ossicles**, etc. Intermediate features include mammary glands without nipples, **acromonial** spines in the scapulae and body temperature between 25–28°C.

Identification—*By flat bill.*

118. *Tachyglossus* (Echidna)

Classification :

Phylum............**Chordata**
Subphylum........**Vertebrata**
Superclass........**Gnathostomata**
} Characters same as those of *Ornithorhynchus*.

Class...............**Mammalia** → Body covered with hairs, skin has several glands, skull with 2 occipital condyles, heart 4 chambered and females have mammary glands.

Subclass............**Prototheria** → Egg-laying mammals.

Order..............**Monotremata** → Egg-laying mammals with coracoid and precoracoid, without pinna, cloaca present and mammary glands without nipples.

Type...............*Tachyglossus* (Echidna).

Geographical distribution—*Echidna* with several species is distributed in Australia, Tasmania and New Guinea.

Habit and habitat—*Echidna* leads **terrestrial** and **burrowing** life. It is **nocturnal** and feeds on ants, found under stones and is called as anteater.

Comments :

(1) *Echidna* is commonly called as spiny **anteater**.

(2) It is recognized by **strong, pointed spines** and coarse hairs on dorsal side.

(3) Snout is long and tapering. (4) The lower surface has hairs but no spines.

(5) **Eyes** are small without nictitating membrane. (6) **External** ear is absent.

(7) **Girdles** and limbs reptile like. Feet without web.

(8) The second digit of hind limb has a long and curved **toilet claw** to clean spines. The **tarsus** of male has a grooved horny **poison spur**.

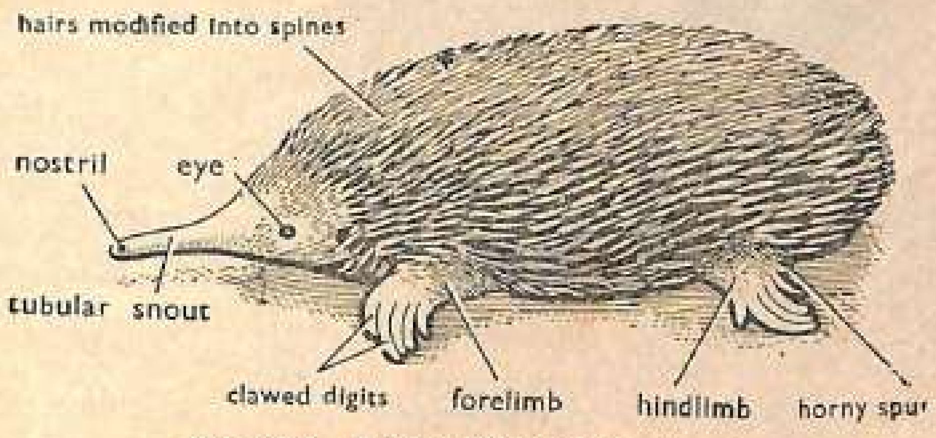


Fig. 3-122. *Echidna*. (Spiny anteater).

(9) The male also possesses mammary glands secreting milk and this condition is called as **gynaecomastisus**, where both parents nourish young ones. Teats absent.

(10) Female lays one egg which is probably carried in pouch (**marsupium**) on abdomen.

Special feature—*Echidna* has phylogenetic significance, as it serves a link between reptiles and mammals. The animal is specialized for ant eating. The jaws are pointed forming a rostrum devoid of any teeth. Tongue is protrusible. The posterior region of the tongue is serrated to grind insects and the secretion of salivary glands neutralizes formic acid of ants.

Identification—*By tubular snout and spiny body.*

119. Erinaceus

Classification :

Phylum..............**Chordata**
Subphylum..........**Vertebrata**
Superclass..........**Gnathostomata**
Class................**Mammalia**
(Characters same as those of *Echidna*.)
Subclass............**Theria**
Infraclass...........**Eutheria** → Placental mammals, no marsupial bones or pouch, vagina single, foetus attached to uterus by placenta and is born fully developed.
Order................**Insectivora** → Feet 5 toed, inner toes not opposable.
Type.................*Erinaceus* (Hedgehog).

Geographical distribution—*Erinaceus* is found in northern hemisphere, West Indies, Africa and India. **Cretaceous** to **Recent**.

Habit and habitat—*Erinaceus* inhabits holes and bushes during day and it comes out during night to feed. It is **omnivorous**, feeding on fruits, roots, insects, worms, slugs and other small animals. Hedgehog hibernates during winter. When alarmed or disturbed, it has the habit of rolling its body like a spiny rounded ball.

Comments :

(1) *Erinaceus* is commonly called as **hedgehog.**

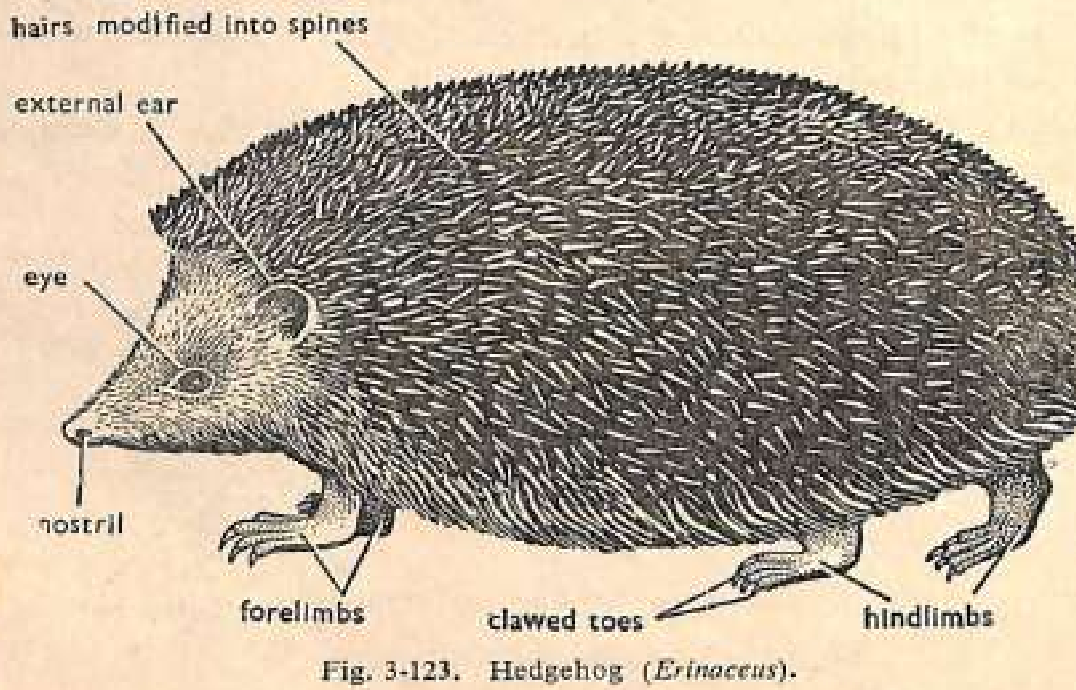


Fig. 3-123. Hedgehog (*Erinaceus*).

(2) The animal is characterized by the presence of sharp outwardly directed spines on dorsal side, while ventral side has soft fur.

(3) A muscle band is found over neck and sides to move spines.

(4) **Tail** is small. (5) **Eyes** are small, **pinnae** and **legs** are short.

(6) No **marsupial** bone or **pouch**.

(7) **Vagina** single; foetus develops entirely within body of female, attached by a placenta to wall of uterus.

(8) Feet usually 5-toed, with claws, inner toes opposable.

(9) Teeth sharp pointed, 36 in number. Ribs 14–15.

(10) Snout usually long and tapered. (11) Mouth tubular.

120. *Talpa* (Mole)

Classification :

Phylum............**Chordata**	Characters same as those of *Erinaceus*.
Subphylum.......**Vertebrata**	
Superclass.......**Gnathostomata**	
Class.............**Mammlia**	
Subclass..........**Theria**	
Infraclass........**Eutheria**	→ Placental mammals, no marsupial bones or pouch, vagina single, foetus attached to uterus by placenta and is born fully developed.
Order............**Insectivora**	→ Feet 5 toed, inner toes not opposable.
Type............. *Talpa*.	

Geographical distribution—*Talpa* is found in India (Assam) and the western Himalayas. **Cretaceous to Recent.**

Habit and habitat—*Talpa* is adapted for subterranean burrowing and lives in tunnels. It feeds on small worms, insects and sprouted seeds. It runs deeper into tunnels.

Comments :

(1) *Talpa* is commonly called as **mole**.

(2) The **pigmentation** is uniformly velvet-black, with a silver-grey glossy texture.

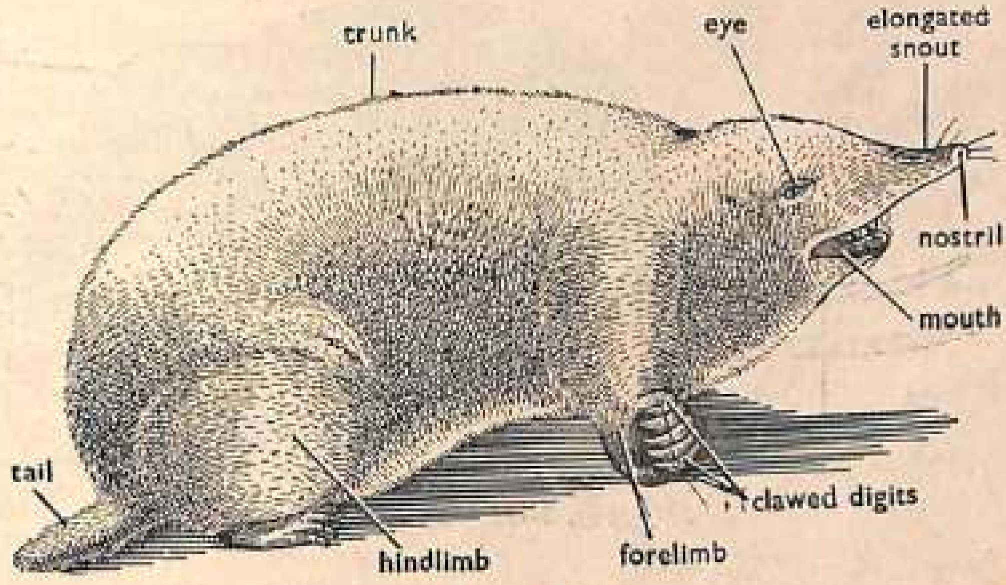


Fig. 3-124. *Talpa*.

(3) **Tail** and feet are fleshy white. (4) It measures 15 cms. in length.

(5) The **head** is wedge-shaped, having prenasal bone in snout which is elongated. Teeth sharply pointed.

(6) The eyes are very much reduced and covered with skin and external ear (pinna) absent.

(7) **Tail** is short, sensory and without hair.

(8) The manus is large and broad containing 5 digits, each having broad nail. The hand is used for digging.

(9) **Feet** usually 5 clawed toes; inner toes not opposable.

(10) No **marsupial** pouch. Single vagina. Foetus develops within the body of female attached by a placenta to wall of uterus.

121. *Sorex*

Classification : Same as those of *Talpa*.

Geographical distribution—*Sorex* is found throughout the world. **Miocene to Recent.**

Habit and habitat—*Sorex* lives in burrows feeding voraciously on insects, small invertebrates and some rodents.

Comments :

(1) *Sorex* is commonly called as **shrew**. (2) It is **mouse-like** insectivore.

(3) The **snout** is elongated and contains several moustaches.

(4) Eyes are small, rudimentary and not covered.

(5) Entire **body** is covered with steel-grey fur.

(6) The elongated **tail is** covered with **scales**.

(7) **Mammary gland** with definite teats present. (8) **Pinnae** absent.

(9) Pelage short and soft. (10) **Feet** and **tail** normal.

Special feature—*Sorex* is a very ancient genus, found from Miocene and onwards. It has undergone little change.

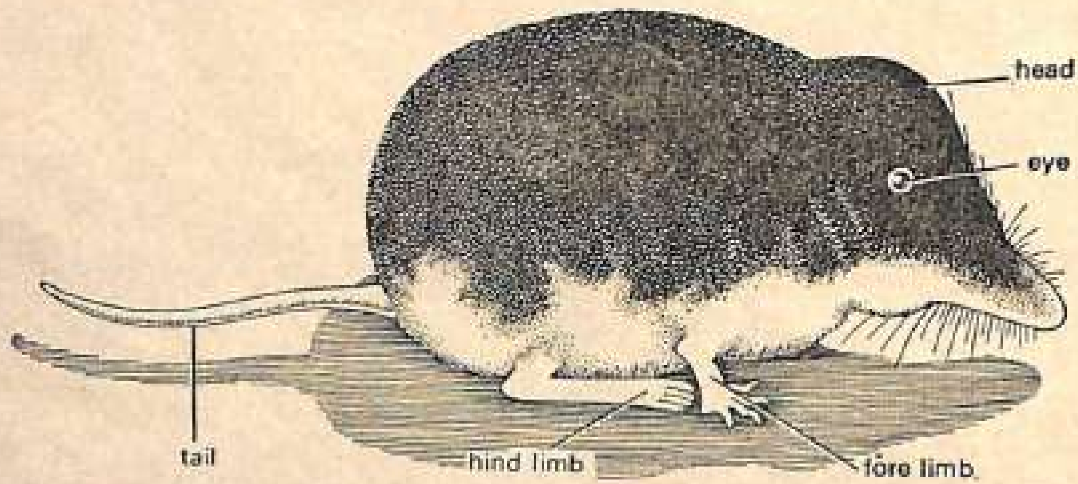


Fig. 3-125. *Sorex*.

122. Loris

Classification :

Phylum............	**Chordata**	
Subphylum........	**Vertebrata**	Charact ers same as those of *Sorex*.
Superclass........	**Gnathostomata**	
Class...............	**Mammalia**	
Subclass...........	**Theria**	
Infraclass........	**Eutheria**	
Order..............	**Primates**	→ Head turns easily on neck. Eyes directed forwards.
Suborder..........	**Lemuroidea**	→ Head with snout.
Type................	*Loris*	

Geographical distribution—Lorises are found outside Madagascar and specially in India and Sri Lanka. **Pliocene to Recent.**

Habit and habitat—*Loris* is a **solitary, nocturnal and arboreal primate.**

Comments :

(1) The body of *Loris* is covered with brownish fur with silvery look. Fur is thick and woolly.

(2) Head is small and is produced into snout.

(3) Eyes are closely placed. They are very distinct and bulging.

(4) External ear or pinna is conical.

(5) Nostrils in the form of small apertures.

(6) Some toes with claws, others with flat nails.

(7) Tail long but not prehensile.

(8) Forelimbs and hindlimbs elongated.

(9) Teeth thecodont and heterodont.

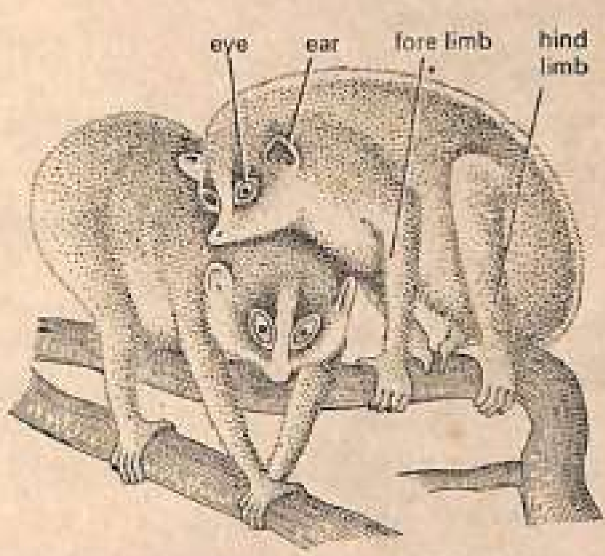


Fig. 3-126. *Loris*.

(10) The locomotion is remarkably slow and deliberate. It is often found hanging upside down.

(11) They seem to be survival of an earlier stock.

Special feature—In Lorises traces of very early features remain, including a transverse fold of skin on the abdomen of the female, which is considered by some to represent a marsupium. They show some features that recall the higher primates. For example, the tympanic ring is fused to the petrosal bulla. The face in some is shorter and brain rounder than in true lemurs.

123. Pteropus

Classification :

Phylum............	**Chordata**	
Subphylum.......	**Vertebrata**	Characters same as those of *Loris*.
Superclass.......	**Gnathostomata**	
Class..............	**Mammalia**	
Subclass..........	**Theria**	
Infraclass.........	**Eutheria**	
Order..............	**Chiroptera**	→ Flying mammals, small size and capable of true flight.
Suborder..........	**Megachiroptera**	→ Head and body large.
Type...............	*Pteropus* and *Cynopterus*.	

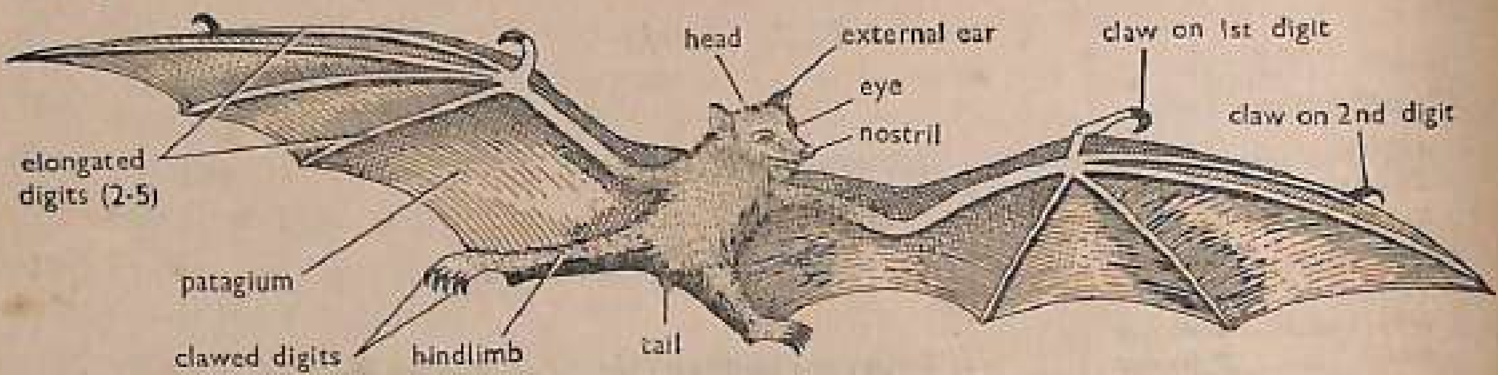


Fig. 3-127. *Cynopterus*. Indian fruit bat.

Geographical distribution—*Pteropus* is found in South-eastern Asia, especially in India. **Pliocene** to **Recent.**

Habit and habitat—*Pteropus* is adapted for arboreal and aerial mode of life. They live in groups and feed on fruits (**fruigivorous**) and often damage orchards. They sleep by day on tree branches.

Comments :

(1) *Pteropus* is commonly called **Fruit bat** or **Flying fox** and in Hindi **Chamgadar.**

(2) It is capable of **true flight**.

(3) The forelimbs are equal and included with tail in a wide, and thin fur covered **"parachute"** or **patagium.**

(4) Body is dark-brown coloured and shoulders are golden yellow.

(5) Forelimbs and 2nd to 5th digits long. Only 1st and 2nd digits of forelimbs clawed.

(6) **Hind feet** small with sharp curved claws. (7) **Teeth** small. (8) **Tail** small and stumpy.

(9) **Ears** are small, oval and two edges of the ear are in contact with the base.

(10) **Eyes** are large.

(11) During sleep, head hangs downwards with wings folded cloak-like around body.

Special feature—Bats are important due to five reasons :

(i) They have phylogenetic significance with insectivores. (ii) They are the only flying mammals. (iii) They are used for experimental purposes (iv) Faeces of bats are used as fertilizer. (v) Bats have highly developed **Sonar** or **Echo-apparatus**—a kind of radar. While flying they constantly send out ultrasonic sound waves consisting of **periodic clicks**, which strike on object or wire and are reflected back to bat. Rate of click increases 50–150 seconds as the object is approached. **Ultrasonic sounds** are produced from the vocal cords.

Identification—*By patagium.*

124. *Manis*

Classification :

Phylum..................	**Chordata**	
Subphylum..............	**Vertebrata**	Characters same as those of *Pteropus*.
Superclass..............	**Gnathostomata**	
Class......................	**Mammalia**	
Subclass..................	**Theria**	
Infraclass................	**Eutheria**	
Order......................	**Pholidota**	→ Body covered by large overlapping horny plates.
Type.......................	*Manis crassicaudata.*	

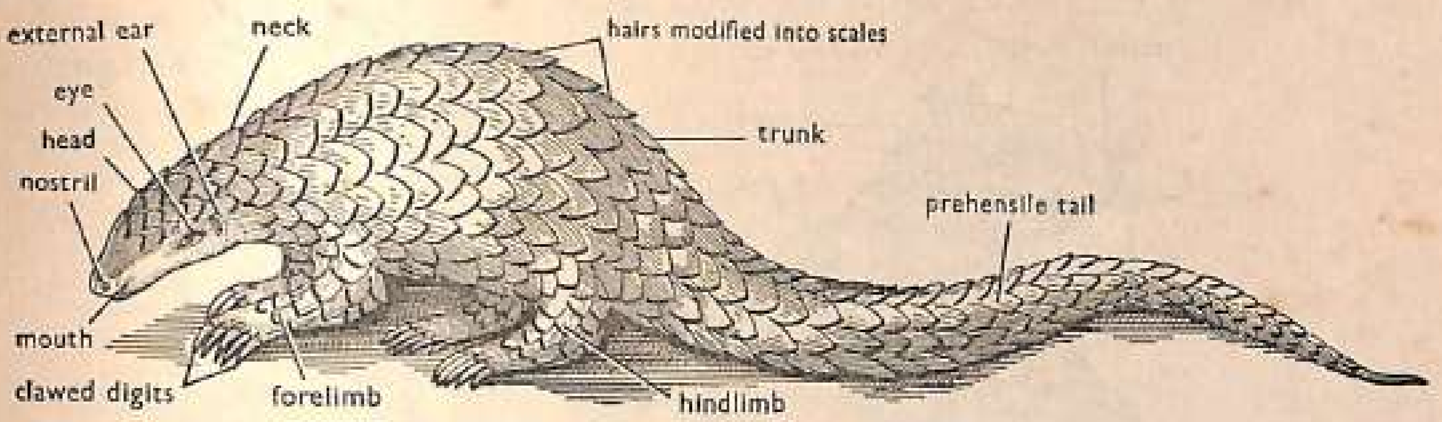


Fig. 3-128. *Manis*. Scaly anteater or pangolin.

Geographical distribution—*Manis* is found in Africa and South-eastern Asia, India (Assam), Sikkim, Nepal and the Himalayas.

Habit and habitat—*Manis* is found in the hilly tracts. It is a **nocturnal** and burrowing mammal. It feeds on ants and termites whose nest is broken by its sharp fore-claws.

Comments :

(1) *Manis* is commonly called as **scaly anteater** or **pangolin.** It measures about 90 cm. in length.

(2) The animal is divided into **head**, neck, body and **tail.** Except snout, head, body, tail and limbs (except claws) are covered by thick horny, **overlapping scales** arranged in longitudinal rows. Scales are thick and striated at the base, yellowish brown or clay coloured.

(3) Between scales coarse hairs are found. (4) **Head** is small with pointed snout.

(5) **Eyes** and **pinnae** are small.

(6) **Tail** is long and broad and contains 16–17 scales in each row. Teeth absent.

(7) **Tongue** is long and glutinous. (8) The lower body surface is covered with **hairs.**

(9) **Pangolins** walk slowly with arched back and the forelimb and anterior surface in contact with the ground.

(10) The **pyloric** stomach works like gizzard of birds, having small pebbles or stones in it and hence it is called as **stone-eater** or **bajrokit.**

(10) When disturbed, it rolls its body with head between the forelegs and tail around body.

Identification—*By scales.*

125. *Funambulus*

Classification :

Phylum............**Chordata**	Characters same as those of *Manis*.
Subphylum........**Vertebrata**	
Superclass........**Gnathostomata**	
Class...............**Mammalia**	
Subclass...........**Theria**	
Infraclass.........**Eutheria**	
Order...............**Rodentia**	→ Gnawing mammals. Incisors chisel-like continually growing, canine absent and a gap is found between incisors and cheek teeth.
Type.................*Funambulus.*	

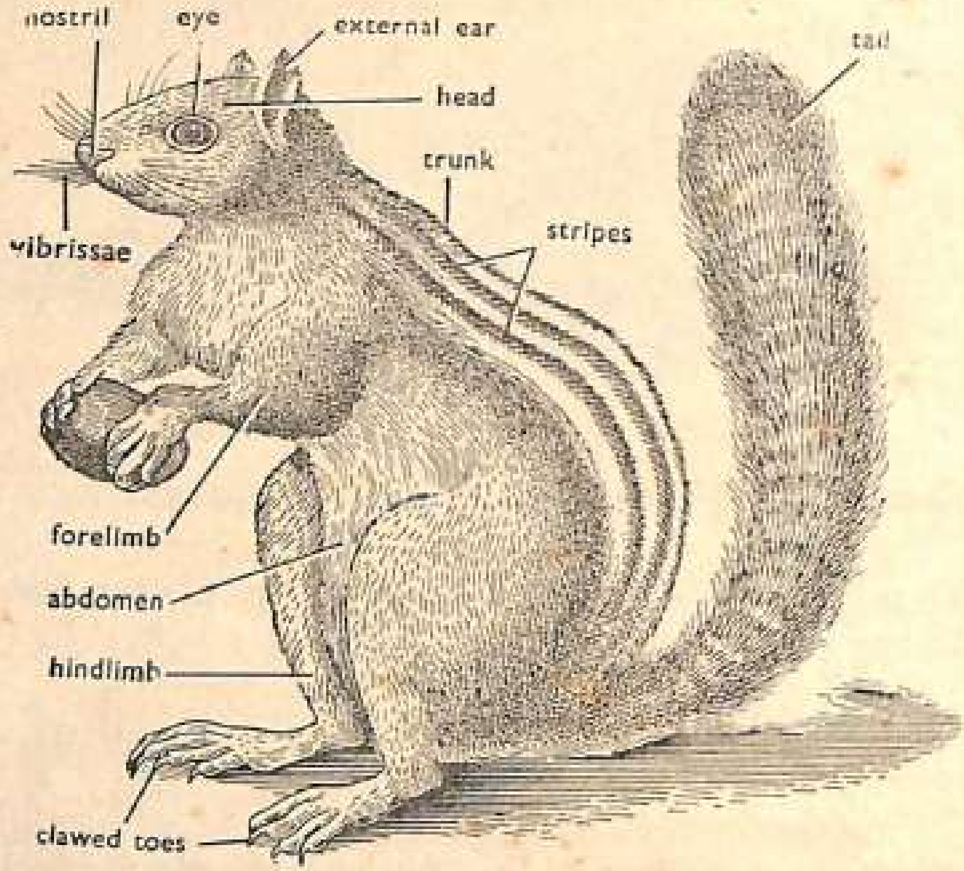


Fig. 3-129. (*Funambulus*) Squirrel.

Geographical distribution—*Funambulus* has world-wide distribution. It is found on all continents and islands. **Eocene to Recent.**

Habit and habitat—*Funambulus* lives on trees, ground and is fast runner. It feeds on fruits and seeds. It builds nests of twigs and leaves. It is **diurnal.**

Comments :

(1) *Funambulus* is commonly called as **squirrel** and in Hindi **Gilahari**.

(2) **Body** contains three white and grey stripes on dorsal side.

(3) The ventral side and limbs covered by small grey hairs.

(4) Stripes absent on neck.

(5) The head (snout) contains several moustaches. Eyes are large.

(6) **Limbs** with 5 toes and claws.

(7) **Incisors** exposed, chisel-like, rootless, grow continuously, gap between **incisors** and cheek teeth, **canine** absent and upper and lower cheek teeth about equal size. Palate narrow. Elbow joint rotates.

(8) Pinnae well developed. (9) Tail is elongated and bushy.

(10) Squirrel is also used for experimental purposes. It is largely used in cancerous studies.

Identification—*By bushy tail.*

126. *Rattus rattus*

Classification :

Phylum	**Chordata**	Characters same as those of *Manis.*
Subphylum	**Vertebrata**	
Superclass	**Gnathostomata**	
Class	**Mammalia**	
Subclass	**Theria**	
Infraclass	**Eutheria**	
Order	**Rodentia**	→ Incisors well developed.
Type	*Rattus rattus.*	

Geographical distribution—*Rattus rattus* is found in all parts of the world. It prefers warmer and drier conditions. **Eocene to Recent.**

Habit and habitat—*Rattus rattus* is a common rat inhabiting holes and burrows in the houses and in cultivated fields. It feeds on stored grains.

Comments :

(1) *Rattus rattus* is commonly called as **black rat.**

(2) It is considered as parasite of man.

(3) Head and body are covered with black hairs.

(4) Tail is elongated.

(5) **Viviparous.**

(6) Pinnae well developed.

Special feature—Rat destroys the crop and stored grains. It also spreads **typhus** fever and plague. It acts as carrier of these diseases. Rat has great experimental value. It is largely used in various biophysical and biochemical studies.

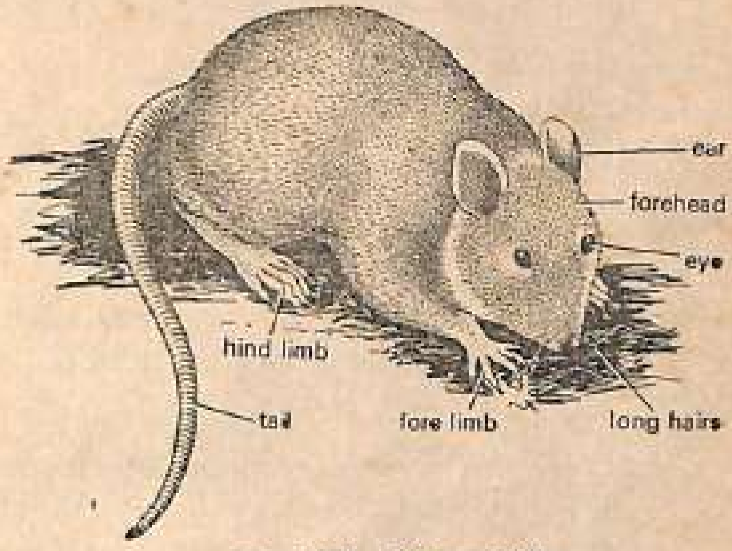


Fig. 3-130. *Rattus rattus.*

127. *Hystrix*

Classification :

Phylum	**Chordata**	Characters same as those of *Manis.*
Subphylum	**Vertebrata**	
Superclass	**Gnathostomata**	
Class	**Mammalia**	
Subclass	**Theria**	
Infraclass	**Eutheria**	
Order	**Rodentia**	→ Gnawing mammals. Incisors chisel-like continually growing, canine absent and a gap is found between incisors and cheek teeth.
Type	*Hystrix.*	

Geographical distribution—*Hystrix* is found in India. **Eocene** to **Recent.**

Habit and habitat—*Hystrix* commonly inhabits river banks, nallahs and bunds. It comes out only after sunset. It is **nocturnal** and herbivorous.

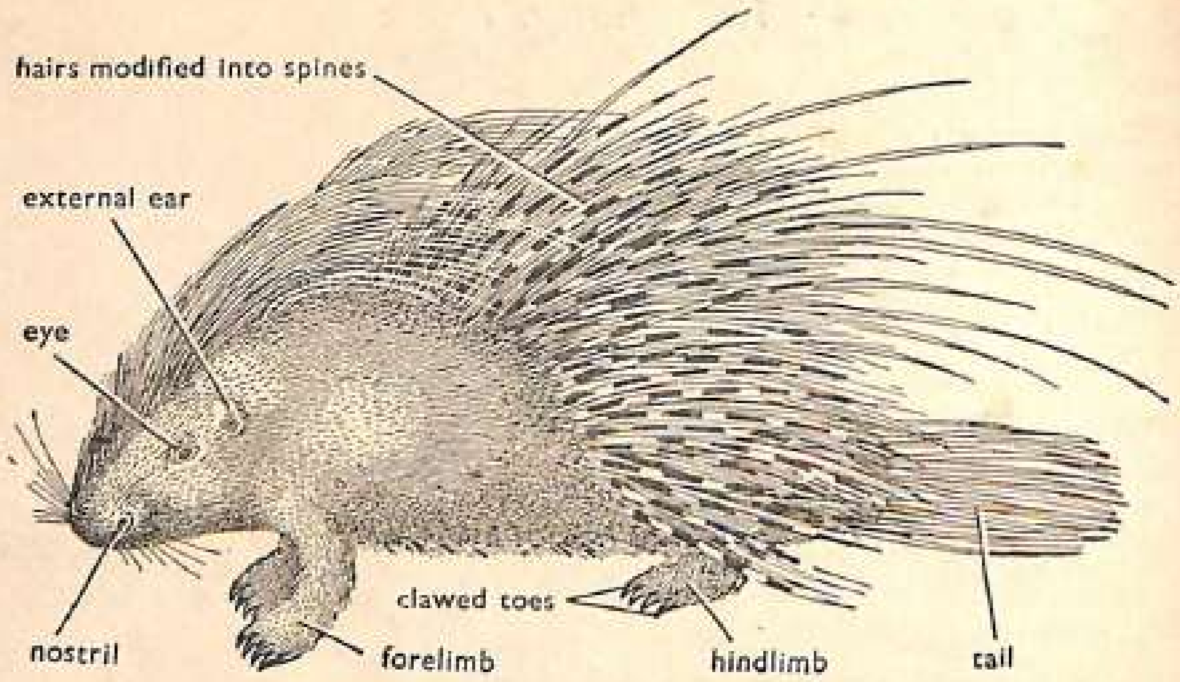


Fig. 3-131. Porcupine (*Hystrix*).

Comments :

(1) *Hystrix* is commonly called as **Porcupine** and in Hindi **Syahi.**

(2) Body of the animal measures about 1 meter.

(3) The unique and outstanding character of the animal is the presence of long spines which are modified **hairs**. The spines are also called as **quills.**

(4) **Snout** is covered with short and stiff bristles. **Face** and **back** contain a few white bristles. **Throat** spines small. Head contains crest of black bristles.

(5) Quills on the loins are mostly white and yellowish-white on tail.

(6) The quills on lumber region are flat and striated. (7) **Head** is produced into snout.

(8) Animal is harmful to crop of potato, carrots and cabbage.

(9) Porcupine often attacks its enemies (dog, etc.) by erecting its spines which penetrate into the flesh of enemy.

(10) Sometimes the animal rolls up in defence.

Identification—*By quills.*

128. Lutra

Classification :

Phylum..........**Chordata**	
Subphylum.......**Vertebrata**	Characters same as those of *Manis*.
Superclass........**Gnathostomata**	
Class...............**Mammalia**	
Subclass...........**Theria**	
Infraclass.........**Eutheria**	
Order..............**Carnivora**	→ Insectivorous mammals.
Type...............*Lutra.*	

Geographical distribution—*Lutra* is found throughout the world. **Eocene** to **Recent**.

Habit and habitat—*Lutra* is found in the rivers throughout India. It aggregates near rocks. It is also terrestrial. They are good and swift swimmers and they catch fish or frogs with remarkable swiftness. They can also be tamed.

Comments :

(1) *Lutra* is commonly called as **otter** or **Udbilao** in Hindi.

(2) *Lutra* is a typical small carnivore with several primitive characters.

(3) Body is elongated with cat-like head.

(4) Head contains small eyes, long hairs and small ears.

(5) Body is covered with short furs.

(6) **Feet** are webbed and other features well suited for water life.

(7) **Teeth thecodont** with well-developed canines.

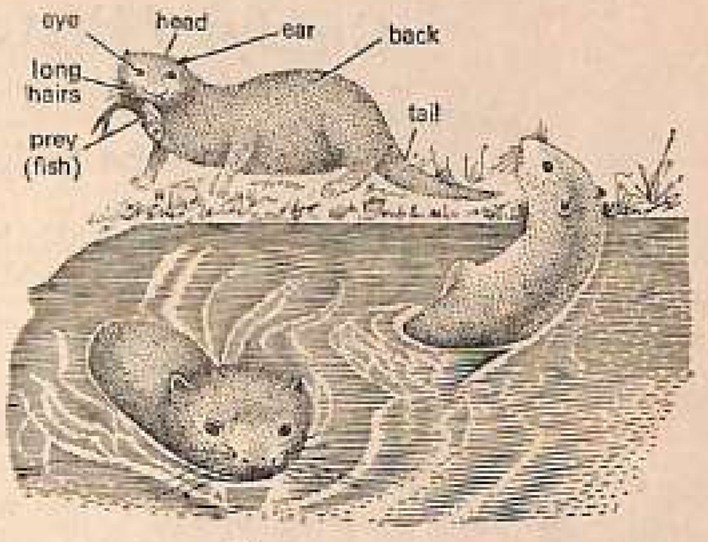


Fig. 3-132. *Lutra*.

129. *Herpestes*

Classification : Same as those of *Lutra*.

Geographical distribution—*Herpestes* is abundantly found in Asian and African countries. **Eocene** to **Recent**.

Habit and habitat—*Herpestes* is a burrowing mammal. It is nocturnal and feeds on ants and termites.

Comments :

(1) *Herpestes* is commonly called as **mongoose** and **Neola in** Hindi.

(2) It is a small and most modified carnivore.

(3) Generally it is like ancestral **miacids** with long skull, small brain and short legs.

(4) Entire body is covered with **greyish fur**.

(5) **Teeth thecodont** and heterodont with well-developed canines.

(6) **Tail** is elongated and bushy. (7) Snout is pointed. (8) **Eyes** small.

(9) Pinna small and rounded.

(10) Forelimbs and hind limbs have 5 digits with fussorial claws.

Special feature—The fight between mongoose and snake is famous but ultimately the former wins and kills the latter.

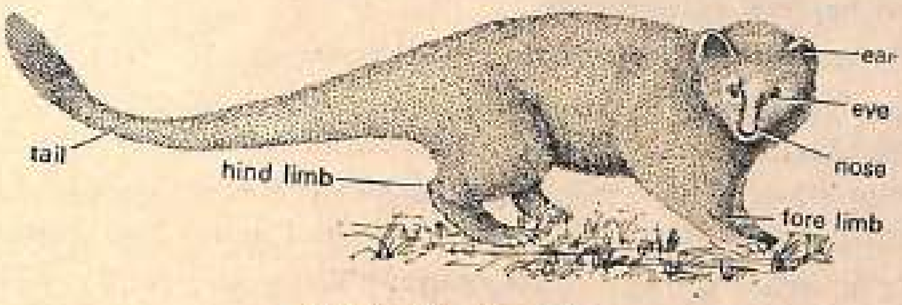


Fig. 3-133. *Herpestes*.

Chapter **4**

Study of Histological Slides

Instructions to Study the Slides

(1) The foremost mechanics of slide study is to know the theoretical histological account in details.

(2) While studying slides keep in mind about the instruction given by the teacher.

(3) First observe the slide in low magnification and if structures are not clear, study it under high magnification or even in oil immersion lens.

(4) Draw the slide on the copy after studying all the details. Keep in mind about the proportion and topography of various parts.

(5) While writing comments, do write about the special feature of the section. For example, in T.S. of the mammalian kidney, cortex and medulla must be clearly shown and structure and function of nephrons must be written.

(6) Study and label the various parts with the help of the Practical Book.

A. PROTOCHORDATES

[1] BALANOGLOSSUS—T.S. of the Collar Region.

Comments :

(1) The collar is a short cylindrical that overlaps the proboscis stalk anteriorly and ventrally contains mouth. T.S. passing through collar region is circular in outline and shows **body wall layers,** collar groove, coelom and buccal cavity.

(2) **Body wall** is composed of **epidermis, nervous layer, basement membrane** and **musculature.**

(3) **Epidermis** covers the entire body surface. It is composed of **ciliated** and **secretory** cells. Ciliated cells contain cilia. Secretory cells may be goblet-shaped or long granular mucus-secreting cells. Some **amylase-secreting mulberry cells** may also be there.

(4) **Nervous layer** in the form of thick layer, consisting of nerve cells and fibres, is found immediately beneath the epidermis.

(5) **Basement membrane** is present just beneath the nervous layer.

(6) **Musculature** is poorly developed in the collar region and comprises of outer circular muscle fibers. Longitudinal muscle fibers absent in the collar region.

(7) **Buccal cavity** is a wide chamber. Histologically it is composed of visceral peritoneum, circular muscle layer, longitudinal muscle layer and inner epithelium.

(8) Dorsal side of section contains **collar groove.** The groove is quite deep.

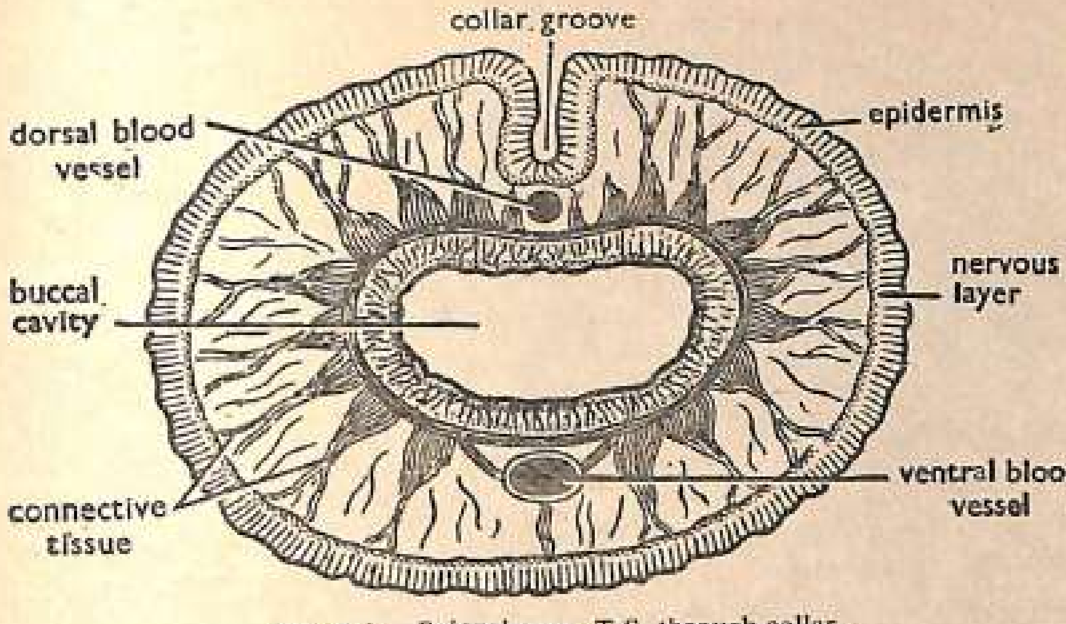


Fig 4-1. *Balanglossus*. T.S. through collar.

(9) The collar **coelomic sacs** are occupied by the **connective** tissue and muscle bundles. The **mesenteries** are incompletely found between buccal cavity and body wall. **Cut** part of dorsal blood vessel is seen just below the end of the collar.

(10) Two perihaemal spaces are present just below the dorsal blood vessel.

(11) **Ventral blood** is seen below buccal cavity in the axis of the dorsal blood vessel.

Identification—*By collar groove.*

[2] BALANOGLOSSUS—T.S. of the Proboscis

Comments :

(1) Proboscis is highly muscularised and adapted for burrowing. While burrowing in the sand, proboscis along with the collar is pushed forwards in the sand and then whole body is **pulled** forwards. In order to bear the stress of pushing, longitudinal muscles are well developed. T.S. passing through proboscis at maximum breadth shows body wall layers, heart vesicle or central complex and buccal diverticulum.

(2) **Body wall** is composed of **epidermis, nervous layer, basement membrane and musculature.**

(3) **Epidermis** covers the body surface on all sides. It is composed of ciliated and secretory cells. Ciliated cells contain cilia. Secretory cells may be pear-shaped or long granular mucus-secreting cells. Some amylase-secreting mulberry cells may also be present.

(4) The **nervous layer** is intra-epidermal. It consists of thick layer comprising of nerve cells and fibers.

(5) **Basement** membrane is found just beneath the nervous tissue.

(6) **Musculature** consists of outer circular and inner longitudinal fibers. The longitudinal muscles occupy entire space between central complex and basement membrane. The longitudinal muscle bundles radiate from the body wall layers towards centre.

(7) There is a **dorso-ventral partition** on one radius of the section extending from central complex to the basement membrane.

(8) Central portion contains proboscis coelom, which encloses **central complex, buccal diverticulum** and **glomerulus.** The buccal diverticulum was previously considered as notochord.

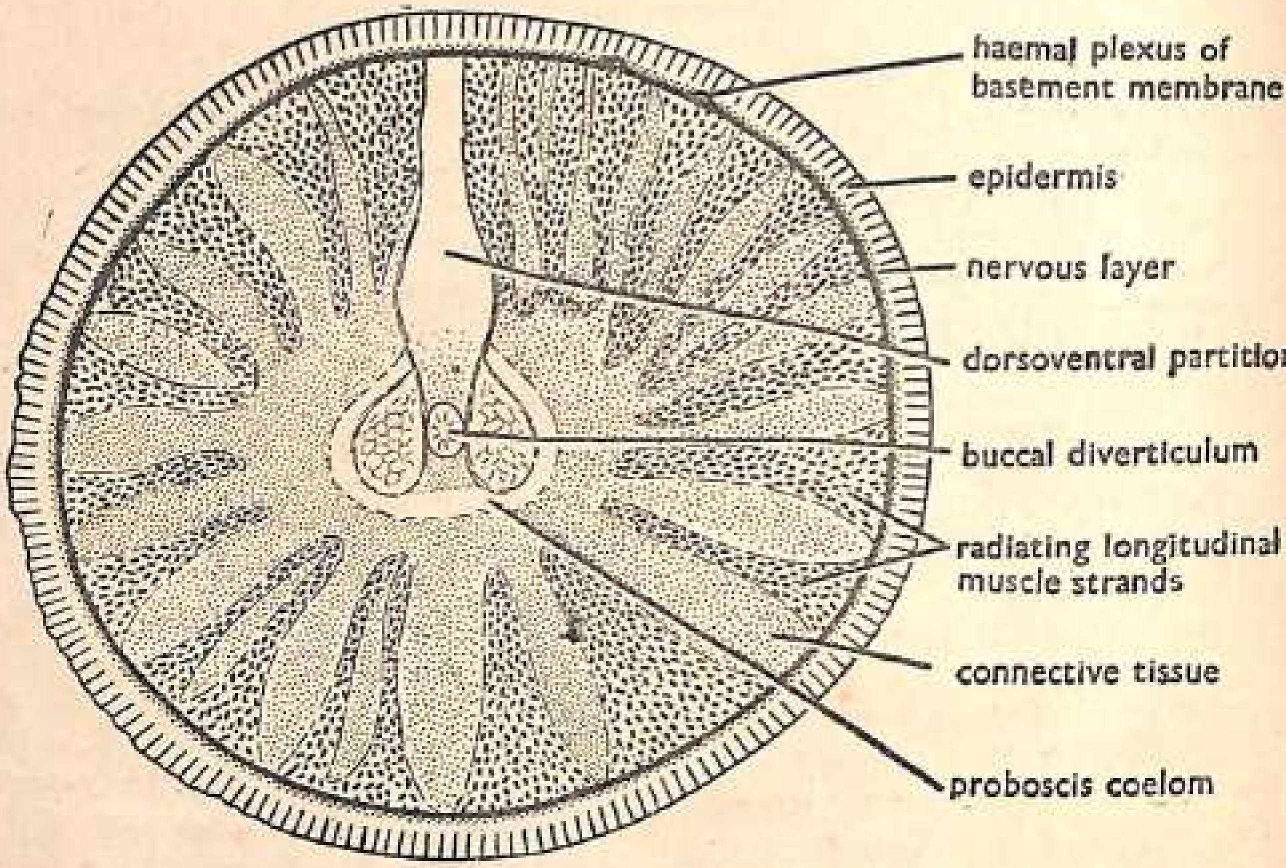


Fig. 4-2. *Balanoglossus*. T.S. through proboscis.

(9) The proboscis coelom is found around central complex. Dorsally two **haemal plexes** of the basement membrane are present.

(10) The proboscis is circular in outline.

Identification—*By dorso-ventral partition.*

[3] BALANOGLOSSUS—T.S. of the Branchiogenital Region

Comments :

(1) The branchial region is differentiated into dorsal, branchial and ventral digestive regions. The branchiogenital region is the anteriormost part of trunk region, Paired **gill slits** are present on the dorsal surface. The sides of the body are produced into flaps or **genital wings**, which contain gonads at various stages of development. **Paired** coelom does not communicate with the proboscis and collar coeloms. T.S. passing through this region shows part of **body wall layers, pharynx, oesophagus** and **genital wings** containing gonads.

(2) **Body wall layer** consists of **epidermis, nervous layer, basement membrane** and **musculature.**

(3) **Epidermis** covers the entire body surface. It is composed of ciliated and secretory cells. Ciliated cells contain cilia. The secretory cells may be goblet-shaped or pear-shaped cells and long granular mucus-secreting-cells. Some **amylase**-secreting mulberry cells may also be present.

(4) **Nervous layer** in the form of thick layer, consisting of nerve cells and fibers, is found immediately beneath the epidermis.

(5) **Basement** membrane is found just beneath the nervous layer.

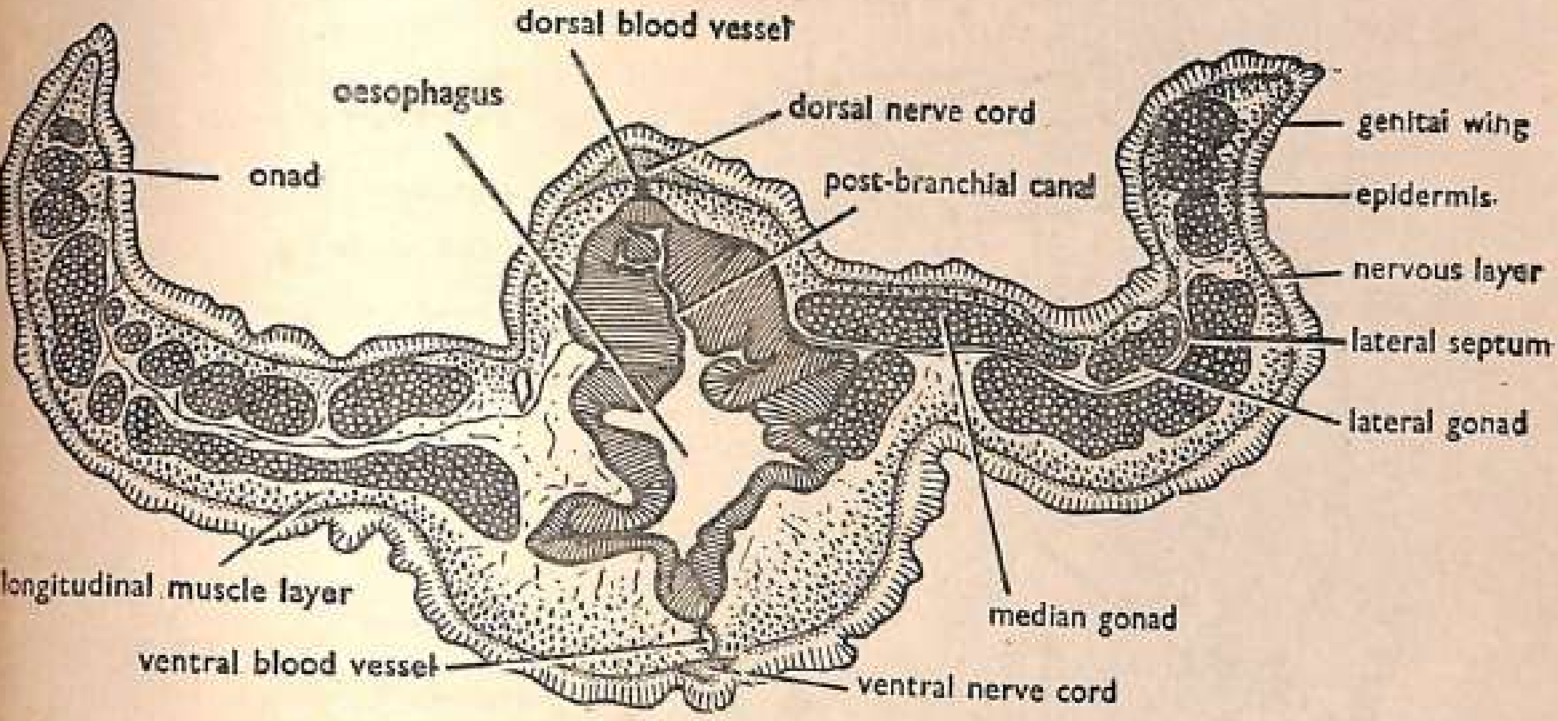


Fig. 4-3. *Balanoglossus*. T.S. through branchiogenital region.

(6) **Musculature**—Longitudinal muscle fibers are clearly seen in the section. Circular muscle fibers absent.

(7) The central space is mostly occupied by the highly muscularised **pharynx**. It is differentiated into upper respiratory **pore-pharynx** and lower digestive pharynx. Oesophagus opens to the exterior by lateral branchial chamber.

(8) Oesophagus is ventral and less muscularised, but with wide lumen.

(9) Nervous layer intra-epidermal. The dorsal nerve cord and dorsal blood vessel and ventral nerve cord and ventral blood vessel are situated in mid-dorsal and mid-ventral positions above and below the pharynx respectively.

(10) Sides are expanded to form genital wings, which contain various cut parts of gonads. The gonads are covered by the epithelial layer. A pair of branchial vessels is present near the junction of pore-pharynx and digestive pharynx. The genital wings are more or less packed with gonads.

Identification—*By the genital wings.*

[4] BALANOGLOSSUS—M.L.S. Anterior Region (Fig. 4-4).

Comments :

(1) The median longitudinal section of the anterior region reveals various histological details of the **proboscis, collar** and **trunk.**

(2) Body wall is composed of epidermis, nervous layer, basement membrane and musculature. The arrangement of muscles varies in different regions.

(3) **Epidermis** forms outer covering and is composed of **ciliated, secretory** and some **amylase** secreting cells.

(4) **Nervous** system is **intra-epidermal**, found below the epidermis.

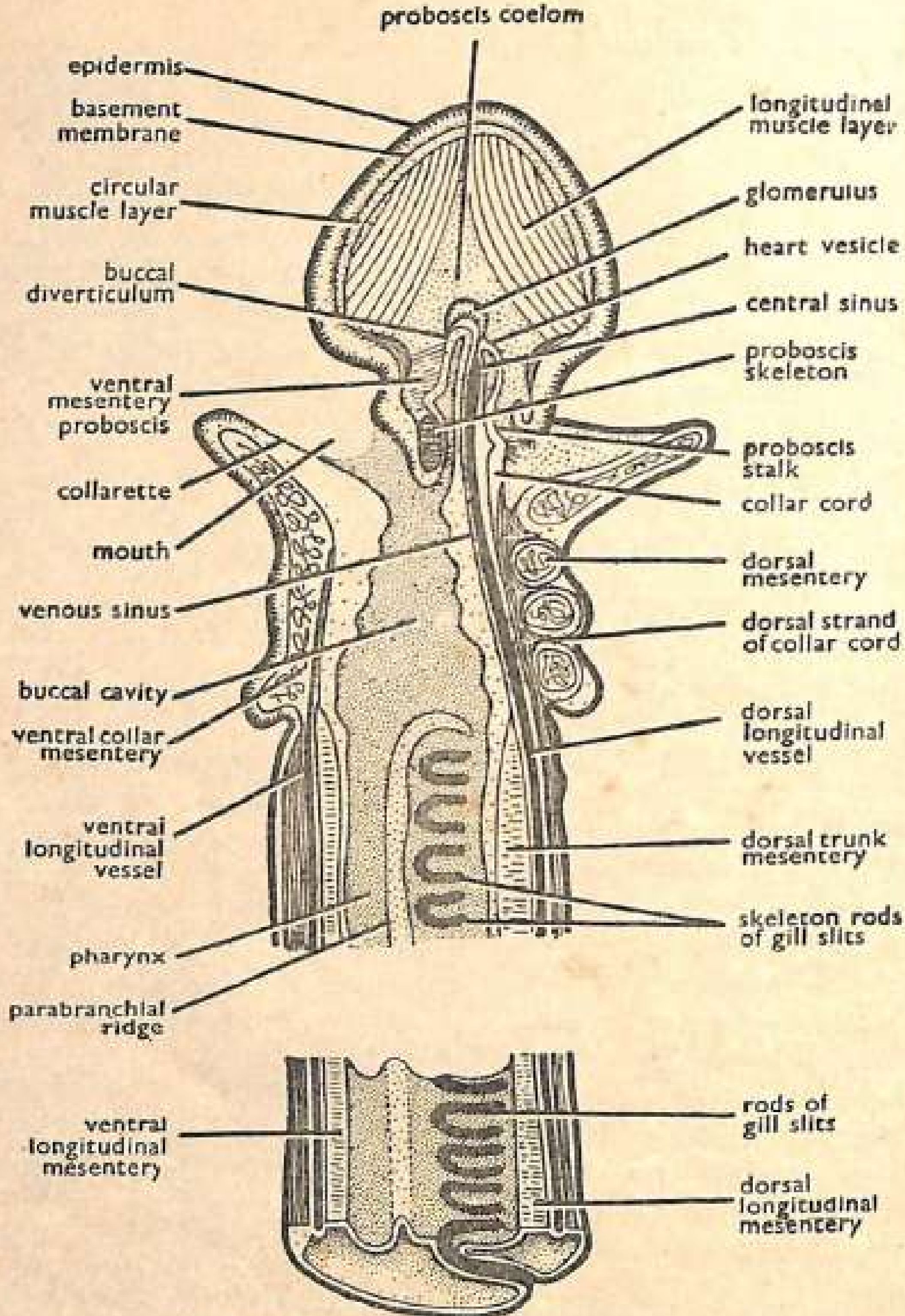


Fig. 4-4. *Balanoglossus* M.L.S. anterior region.

(5) Musculature consists of circular and longitudinal fibers. The arrangement of muscle fibers varies. Proboscis has both circular and longitudinal fibers. Collar has only circular muscle layer, while trunk region has only longitudinal fibers.

(6) In M.L.S. proboscis is tongue-shaped and contains important organs. Anteriorly, it has well-developed longitudinal fibers which surround proboscis coelom.

(7) Posteriorly, **proboscis** has proboscis coelom which contains **central complex**, comprising of proboscis **mesentery**, **buccal diverticulum**, proboscis **skeleton**, central sinus and **heart vesicle**. Just above the buccal diverticulum is **glomerulus**.

(8) **Mouth** is ventrally situated at the junction of proboscis and the collar. It leads into the buccal cavity.

(9) **Collar** region is immediately found below the proboscis. Upper ends of the collar are projected. Below body wall are dorsal collar and ventral collar **mesenteries.** The **dorsal longitudinal** vessel and venous sinus are present which extend into the trunk also. Most of the interior is occupied by the **buccal cavity.**

(10) Below collar is **trunk** region. Prominent structure in this region is the pharynx which is divided into **dorsal respiratory** and **ventral digestive.** Respiratory pharynx is perforated by several **gill slits** having U-shaped tongue bars (skeletal rod). Posteriorly, pharynx opens by a **pore.** Other distinct structures are longitudinal vessels, parabranchial ridge, longitudinal muscles and mesenteries.

Special feature—M.L.S. of the anterior region of *Balanoglossus* reveals that most of the structures are concentrated anteriorly. The important structure present in the proboscis is the buccal **diverticulum** which was previously considered as notochord, but now it is considered as simple pouch with no affinity with notochord. Due to this structure *Balanoglossus* has lost its claim to be included with chordates.

Identification—*By proboscis, collar and trunk.*

[5] BALANOGLOSSUS—T. S. of Post-hepatic Intestine

Comments :

(1) The above T. S. shows make-up of the efferent or posterior intestine.

(2) The body wall is composed of epidermis, nervous layer, basement membrane and muscle layers of longitudinal fibres. Details of the body wall layer is same as in the case of T.S. branchiogenital region of *Balanoglossus.*

(3) The dorsal and ventral **nerve cords** and **blood vessels** are seen in the section.

(4) The **intestine** has wide lumen.

(5) It is lined with endodermal **columnar epithelial** cells.

(6) The **intestine** has a pair of **ciliated** grooves.

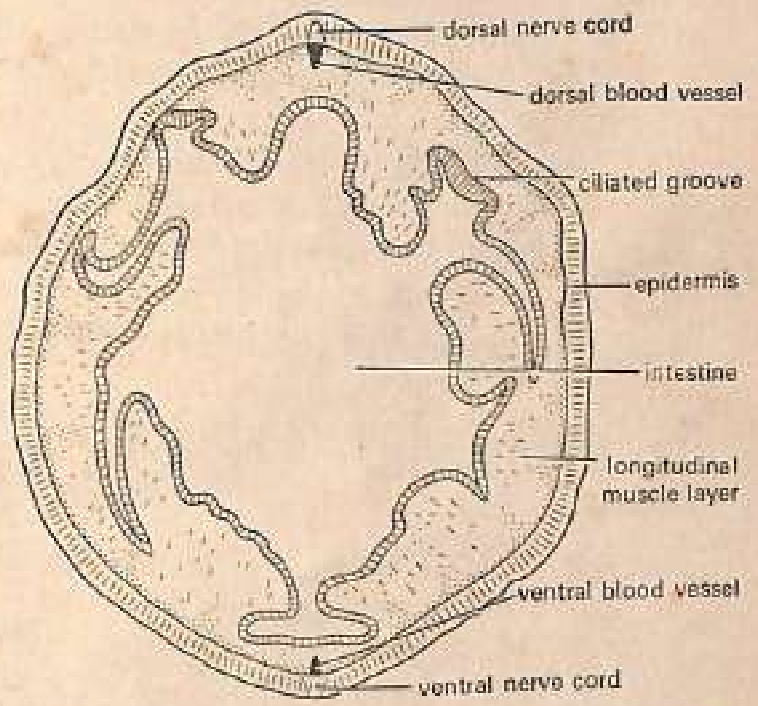


Fig. 4-5. *Balanoglossus*. T. S. Post-hepatic intestine.

(7) Post-hepatic intestine is mainly of **absorptive** nature.

[6] HERDMANIA—Neural Complex

Comments :

(1) Nervous system, excretory system and associated receptor organs are together called as neural complex.

(2) It is composed of **nerve ganglion, neural gland** and **dorsal tubercle.**

(3) The **neural gland** is oval-shaped structure, found in the mantle between two siphons and just above the nerve ganglion.

(4) The **dorsal ganglion** or **nerve ganglion** is solid, elongated structure, found dorsally between branchial and atrial opening. It constitutes **central nervous system.**

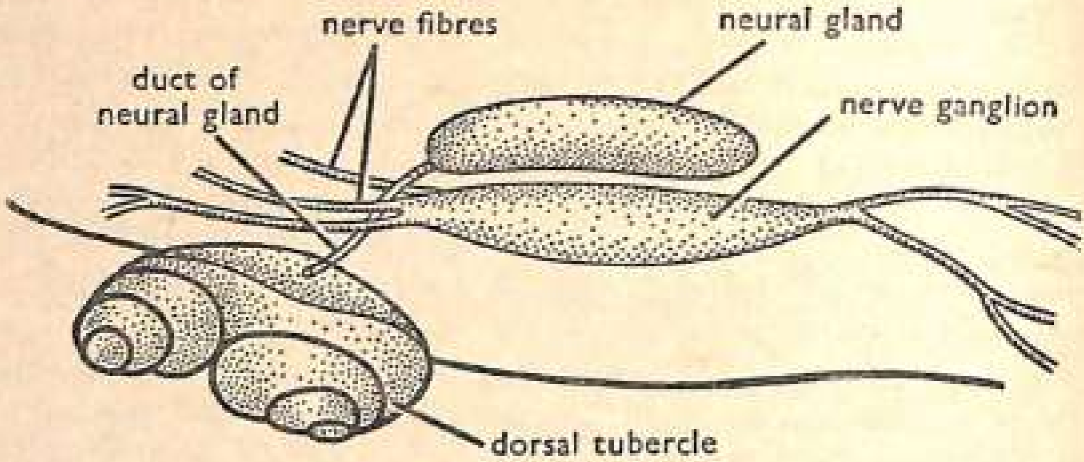


Fig. 4-6. *Herdmania*. Neural complex.

(5) It gives 3 branches to innervate branchial siphon and 2 nerves to atrial siphon.

(6) Experimental removal of the brain indicates that it is not very much needed for the life and metabolic activities.

(7) Anteriorly, neural gland gives a duct, which opens by a ciliated funnel near the base of dorsal tubercle. It contains central tubule, which gives off a few branching peripheral tubules.

(8) Neural gland is supposed to be excretory in function. It secretes excretory material appearing as pigmented granules in the substance of the gland. Cells impregnated with such granules are discharged into the branchial sac.

(9) The dorsal tubercle has a broad base, from which 2 spirally coiled cones originate. Each cone has 3 coils of spirally ciliated channel. The dorsal tubericle is supposed to be chemosensory.

[7] HERDMANIA—Various Spicules

Comments :

(1) Spicules of *Herdmania* are found embedded in the test, body wall and organ systems and are calcareous in nature.

(2) The spicules are of two kinds :

(a) **Microscleres** : These microscopic minute spicules are embedded in test and measure 40–80 microns long. Each spicule has a small knob-like head and an elongated body. The body contains several spiny rings.

(b) **Megascleres** : These are larger spicules ensheathed in a covering and are found in the body wall and other organs. They are of two kinds :

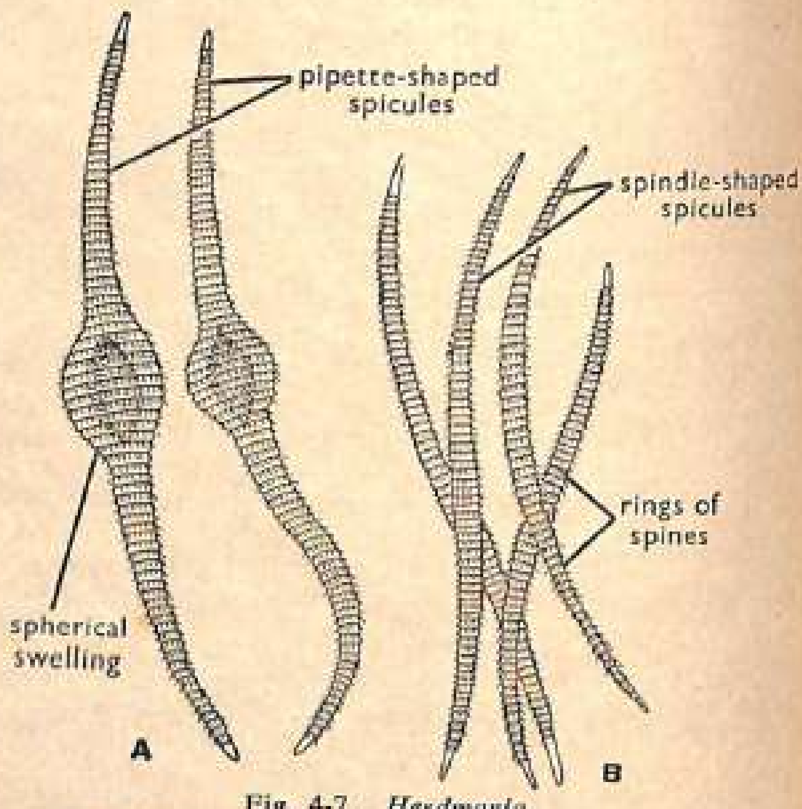


Fig. 4-7. *Herdmania*. A—Pipette-shaped megascleres. B—Spindle-shaped megascleres.

(i) **Spindle-like megascleres**—They are usually found associated with the blood vessels and parts of the alimentary canal. They measure 1·5–2·5 mm. in length and contain 15–20 rings of minute spines.

(ii) **Pipete-shaped megascleres**—These are found in the body wall and particularly in the region of gonads and liver. They are swollen in the middle, pointed at tips and measure 3·5 mm. in length.

Special feature—Spicules protect the animal from predators, they serve to attach body wall with the test, and they also form the framework of certain passages for the blood vessels.

[8] AMPHIOXUS—V. L. S. of The Anterior Region

Comments :

(1) The vertical longitudinal section shows buccal cirri, wheel organ, velum and some pharyngeal region and other following structures.

(2) In a carmine stained section prominent dorsal structures are **fin rays, notochord** and **nerve cord.**

(3) The dorsal fin is low and continuous and is supported by fin rays. Examine from dorsal to ventral sides.

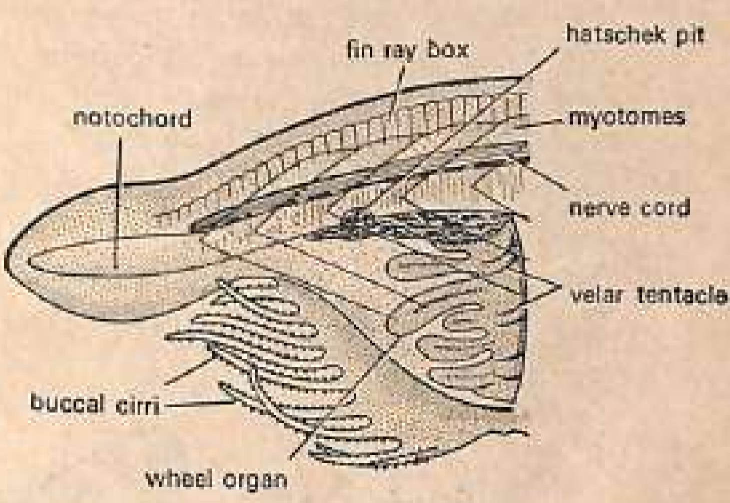


Fig. 4-8. *Amphioxus*. V. L. S. anterior region.

(4) The **nerve cord** or **spinal cord** lies just above the notochord. It contains anterior and posterior pigmented spots and is anteriorly swollen as cerebral vesicle.

(5) The **notochord** in the form of **axial skeletal** rods lies just above the nerve cord. It extends anteroposteriorly.

(6) Anterior end projects as the **rostrum.**

(7) Ventrally **oral hood, vestibule, wheel organ, pharynx** and atrium form important structures.

(8) The **oral hood** is clearly seen with **oral cirri**, which help during feeding by turning inwards to prevent sand particles from passing into the buccal cavity. The oral hood guards the **vestibule.**

(9) At the hinder wall of the vestibule lies a vertical partition called as **velum** with **velar tentacles.**

(10) In front of the velum there is a peculiar **wheel organ** which helps in driving a current of water loaded with food particles into the mouth.

(11) The **pharynx** is quite voluminous structure extending from velum upto the intestine. The pharyngeal wall appears like a network due to the presence of **primary forked** and **secondary** simple **gill bars.** The gill bars separate gill slits and are obliquely directed. Adjacent primary bars are connected by **cross bars** or **synapticulae.**

(12) The floor and roof of the pharynx contain **endostyle** and epipharyngeal groove respectively, and the two connected by **peripharyngeal groove.** All these structures contain cilia which guide the movement of food particles.

(13) **Atrium** is found below the pharynx.

Identification—*By oral cirri and rostrum.*

[9] AMPHIOXUS—T. S. of the Oral Hood

Comments :

(1) At the anterior end there is a median opening encircled by frilled membrane, called as oral hood. The T. S. passing through the oral hood shows body wall, fin ray, nerve cord, notochord, vestiblule and oral hood etc. from dorsal to ventral sides.

(2) The body wall is composed of **epidermis, dermis** or **cutis** and **musculature.**

(3) **Epidermis** is covered by a non-pigmented and iridescent cuticle. Unlike other chordates, the *Amphioxus* epidermis is very thin, composed of single-layered cubical epithelial cells. **Chemoreceptor** cells and unicellular gland cells are also found in the epidermis. No **pigments** in epidermis.

(4) **Dermis** is differentiated into outer fibrous and inner loosely woven fibre layers in which blood capillaries and nerve endings form network.

(5) The **musculature** is very distinct. Thick longitudinal cut segmental blocks or **myotomes** separated by **myosepta** are very distinct.

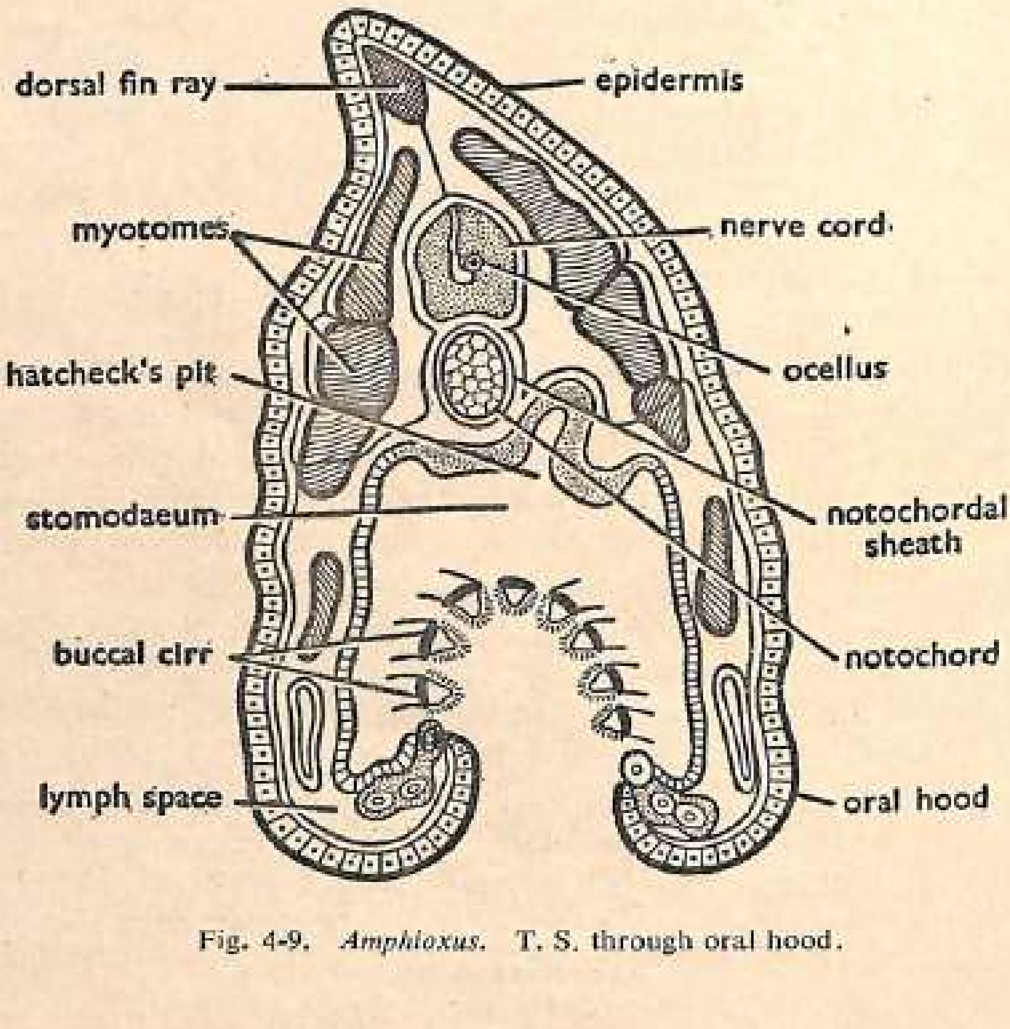


Fig. 4-9. *Amphioxus.* T. S. through oral hood.

(6) Dorsally below the epidermis is a **dorsal fin ray.**

(7) The dorsal tubulated glandular **nerve cord** having a central canal or **neurocoel** and below it notochord are clearly seen.

(8) The **notochord** is composed of chordal or fibrous sheath, which encloses vacuolated notochordal cells filled with homogeneous liquid.

(9) Ventrally section shows large **stomodaeum, oral hood and cut part of buccal cirri in a** circular manner. The oral hood contains **lymph spaces.**

(10) The dorsal wall of the buccal cavity has a sensory Hatscheck's groove.

Identification—*By cut circular* **oral cirri.**

[10] AMPHIOXUS—T. S. of the Pharynx

Comments :

(1) Pharynx is a large elongated, sac-like respiratory and digestive organ, extending from behind velum upto the intestine. **T. S.** passing through anterior pharynx shows **body wall layers, fin ray, nerve** cord, **notochord**, large cut pharynx and metapleural folds.

(2) Body wall is composed of **cuticle**, thin **epidermis, dermis** and **musculature** (*for details of body wall layers* see *Amphioxus* T. S. oral hood).

(3) The dorsal half of the section contains transversally cut thick segmental **myotomes.**

(4) Dorsally just beneath the epidermis is the dorsal fin ray.

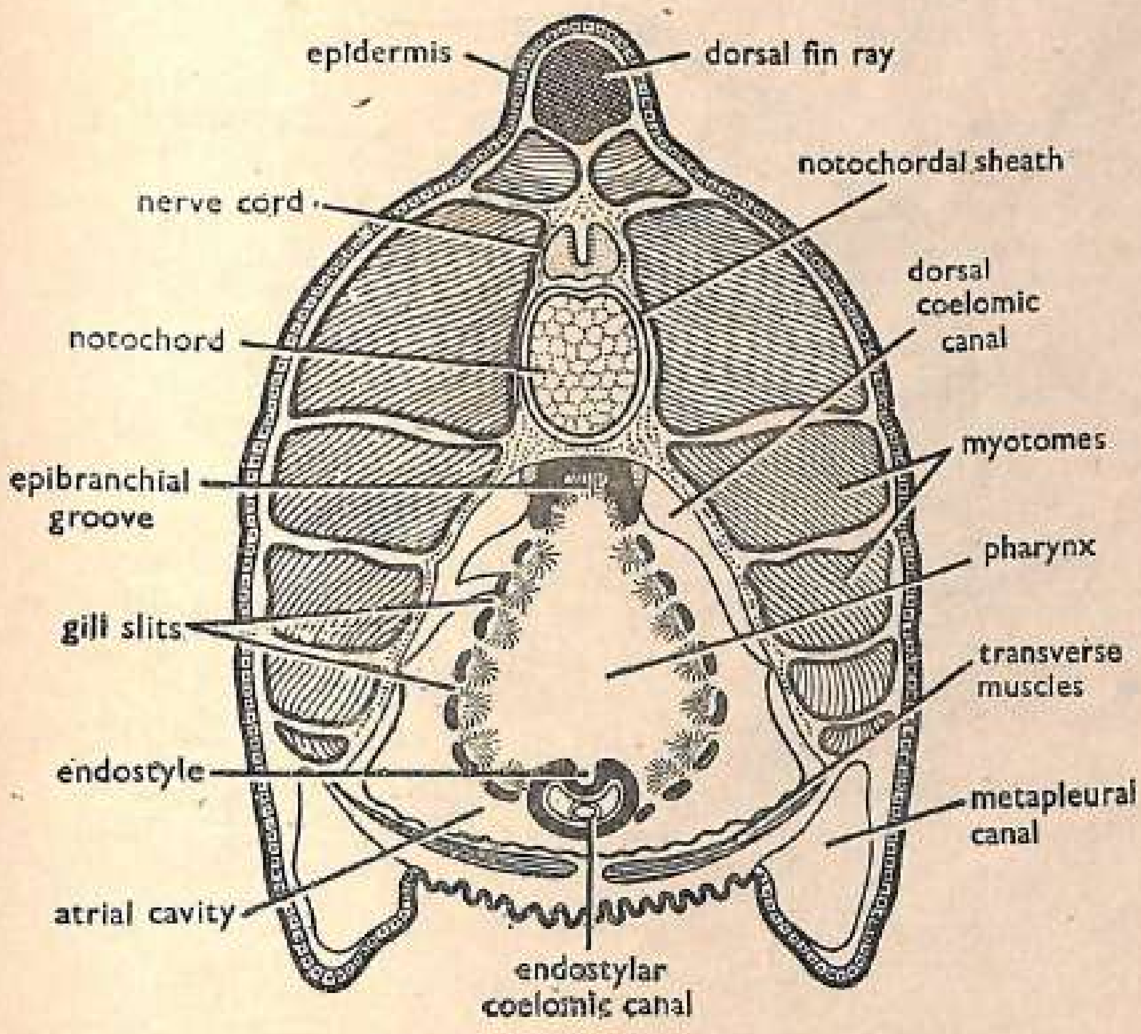


Fig. 4-10. *Amphioxus.* T. S. through Pharynx.

(5) Below **fin ray** is **nerve cord** and beneath nerve cord is **notochord**. The notochord is composed of chordal sheath, which encloses vacuolated notochordal cells filled with homogeneous fluid.

(6) The ventral half of the section contains large pharyngeal cavity.

(7) **Pharynx** is surrounded by the **atrial** cavity.

(8) Pharynx is perforated by gill slits. Pharynx contains longitudinal rows of **cilia** in the form of **epipharyngeal groove** mid-dorsally and **endostyle** enclosing an endostylar canal mid-ventrally.

(9) The ciliated grooves direct food material towards oesophagus. The sides of the pharyngeal cavity contain several gill arches.

(10) Two **metapleural** folds with metapleural cavity are seen posteriorly.

Identification—*By pharyngeal gill slits.*

[11] AMPHIOXUS—T.S. of the Mid-gut, Diverticulum and Ovary

Comments :

(1) T.S. passing through above region shows **body-wall layers**, **nerve cord**, **notochord**, **pharynx**, **mid-gut** and **gonads**.

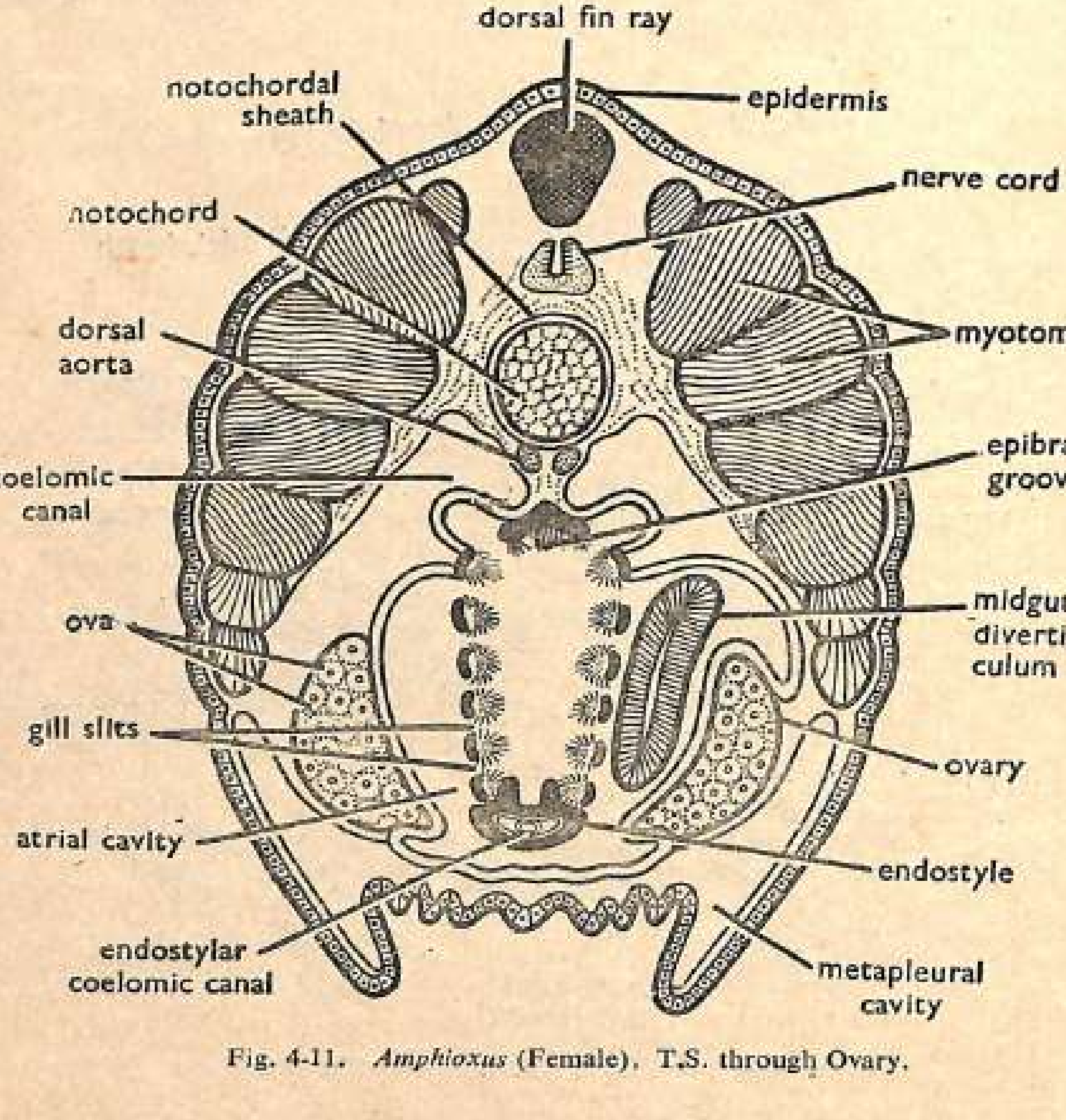


Fig. 4-11. *Amphioxus* (Female). T.S. through Ovary.

(2) Body wall is composed of cuticle, single-layered **epidermis**, **dermis** and **musculature** consisting of alternate segmental **myotomes** and **myocommata.** (*For details of body wall layers* see *T. S. of Amphioxus through oral hood.*)

(3) **Dorsal fin** is seen as raised structure. The dorsal fin ray is found just beneath the epidermis.

(4) Below fin ray is **nerve cord** containing neurocoel.

(5) **Notochord** is found below the nerve cord. It is composed of chordal sheath which encloses vacuolated notochordal cells filled with homogeneous fluid.

(6) A pair of **dorsal aorta** blood vessels is present just beneath the notochord.

(7) Ventral part of section contains two ovaries, mid-gut diverticulum or liver and pharynx.

(8) The **ovaries** are enclosed in coelomic sac and contain several **ova.** Ovaries are found from 25–51 segments.

(9) Mid-gut diverticulum or liver is found on right side of pharynx. It is made up of glandular epithelial cells and secretes digestive enzymes.

(10) Pharynx contains **gill slits**, **epipharyngeal** groove dorsally and endostyle ventrally. Pharynx is surrounded by atrial cavity. Two metapleural folds are seen posteriorly.

Identification—*By liver and ova in ovary.*

[12] AMPHIOXUS—T.S. of the Mid-gut Diverticulum and Testes

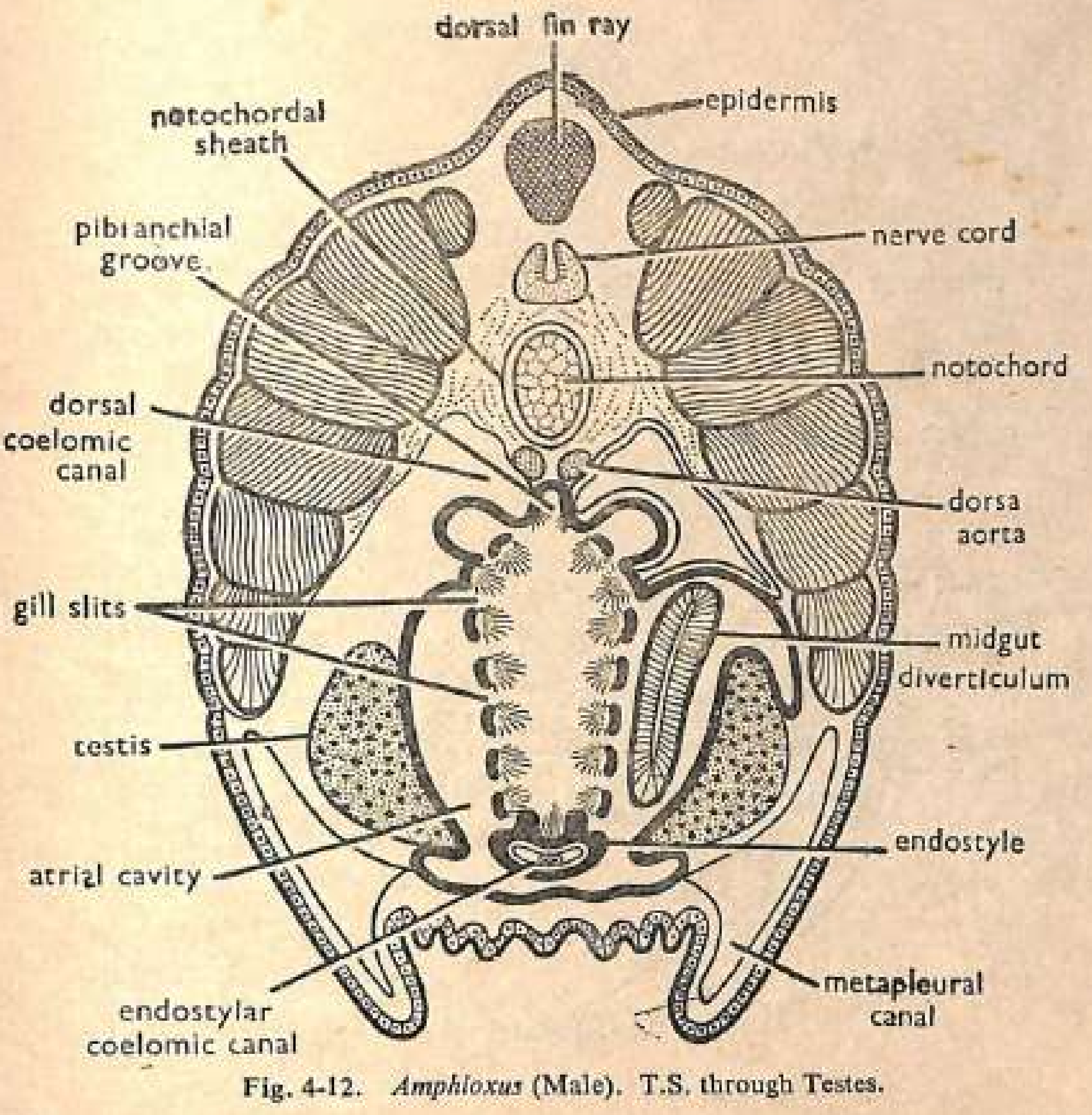


Fig. 4-12. *Amphioxus* (Male). T.S. through Testes.

Comments :

(1) **T.S.** passing through **testis** shows body wall layers, nerve cord and notochord.
(2) The body wall is composed of cuticle, single layered epidermis and musculature consisting of alternate segmental **myotomes** and **myocommata**. *(For details of body wall layers see T.S. of Amphioxus through the oral hood.)*
(3) **Dorsal fin ray** is found below the epidermis.
(4) **Nerve cord** is found below the fin ray. It has **neurocoel.**
(5) **Notochord** is found below the nerve cord. It is composed of chordal sheath which encloses vacuolated notochordal cells filled with the homogeneous fluid.
(6) **Dorsal aorta** blood vessels are seen just below the notochord.
(7) **Pharynx** contains dorsal **epipharyngeal groove, ventral endostyle** and on sides several **gill clefts.** Pharynx is surrounded by atrial cavity.
(8) **Mid-gut** diverticulum is found on right side of the pharynx. It secretes digestive enzymes.
(9) **Testes** are found on both sides having several dot-shaped cut **spermatozoa.** They occupy some topography as ovaries in females.
(10) The **metapleural** folds and metapleural canals are seen posteriorly.

Identification—*By dot-shaped spermatozoa.*

[13] AMPHIOXUS—T. S. of the Mid-gut or Intestine

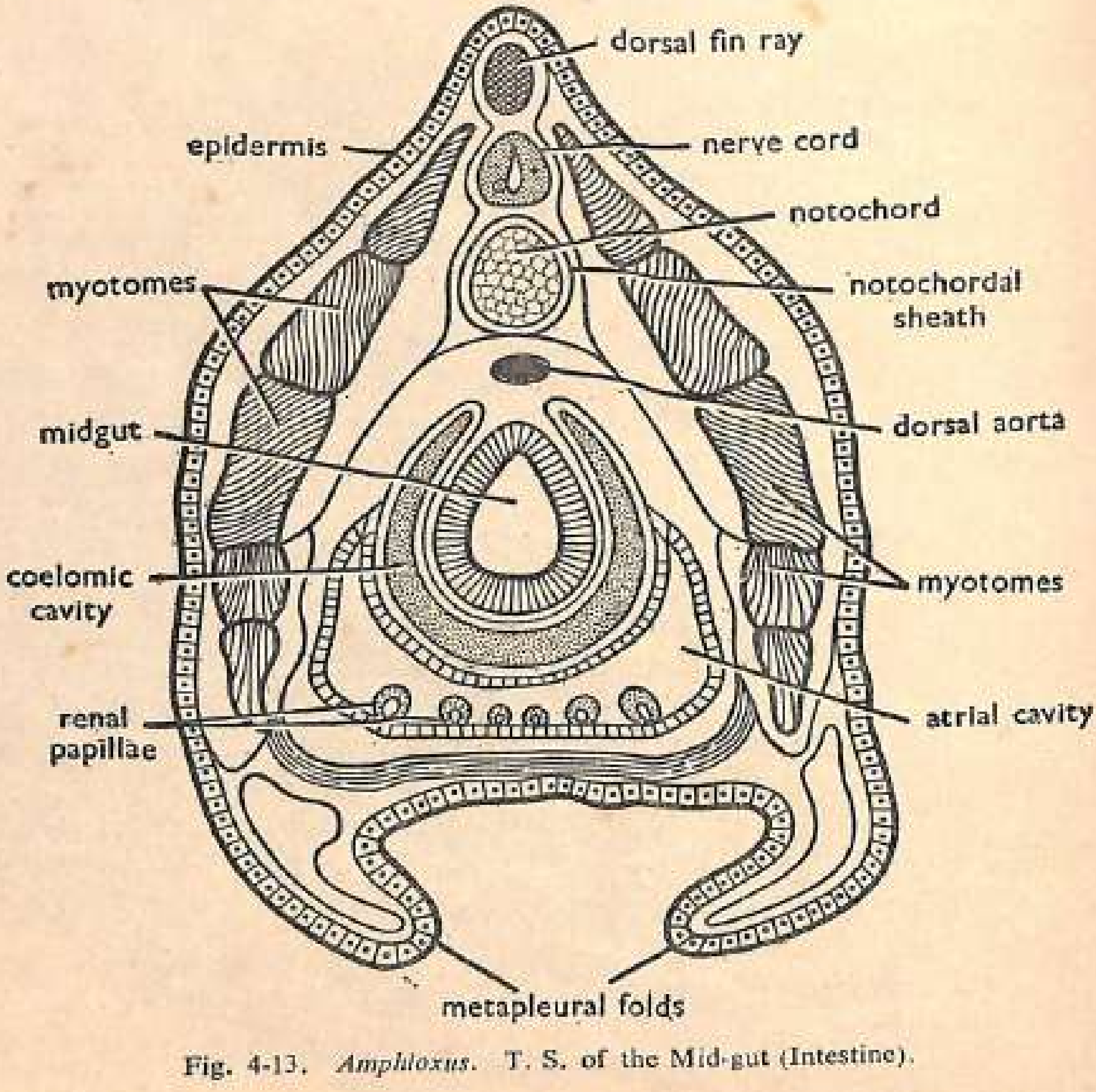


Fig. 4-13. *Amphioxus.* T. S. of the Mid-gut (Intestine).

Comments :

(1) Intestine is found in the posterior region. T. S. passing through the intestine shows usual **body** wall layers, **nerve** cord, **notochord**, **intestine** and **metapleural** folds.

(2) **Body wall** is composed of cuticle, thin epidermis, dermis and muscle bundles consisting of alternate **myotomes** and **myocommata**. (*For details of body wall layers see T. S. Amphioxus through oral hood.*)

(3) The **dorsal fin ray** is found below the epidermis.

(4) The **glandular nerve cord** is found below the dorsal fin ray. It encloses central canal or neurocoel.

(5) The **notochord** is with vacuolated chordal cells, found below the nerve cord.

(6) There is a single dorsal aorta below the notochord.

(7) The ventral half of the section contains mid-gut, coelomic cavity and atrial cavity.

(8) The **mid-gut** or intestine is found in the centre, composed of large **endodermal cells.** Mid-gut is enclosed by coelomic cavity.

(9) Below coelom a well-developed atrium is present. Internally atrial cavity contains **renal papillae.** The food particles escaping from the gill slits reach into the atrial cavity, where they are engulfed by the phagocytic cells contained in the renal papillae.

(10) Below atrial cavity **transverse muscles** and **metapleural folds** are present.

Identification—*By the absence of gill slits and by the presence of intestine and renal papillae.*

[14] AMPHIOXUS—T. S. of the Atriopore

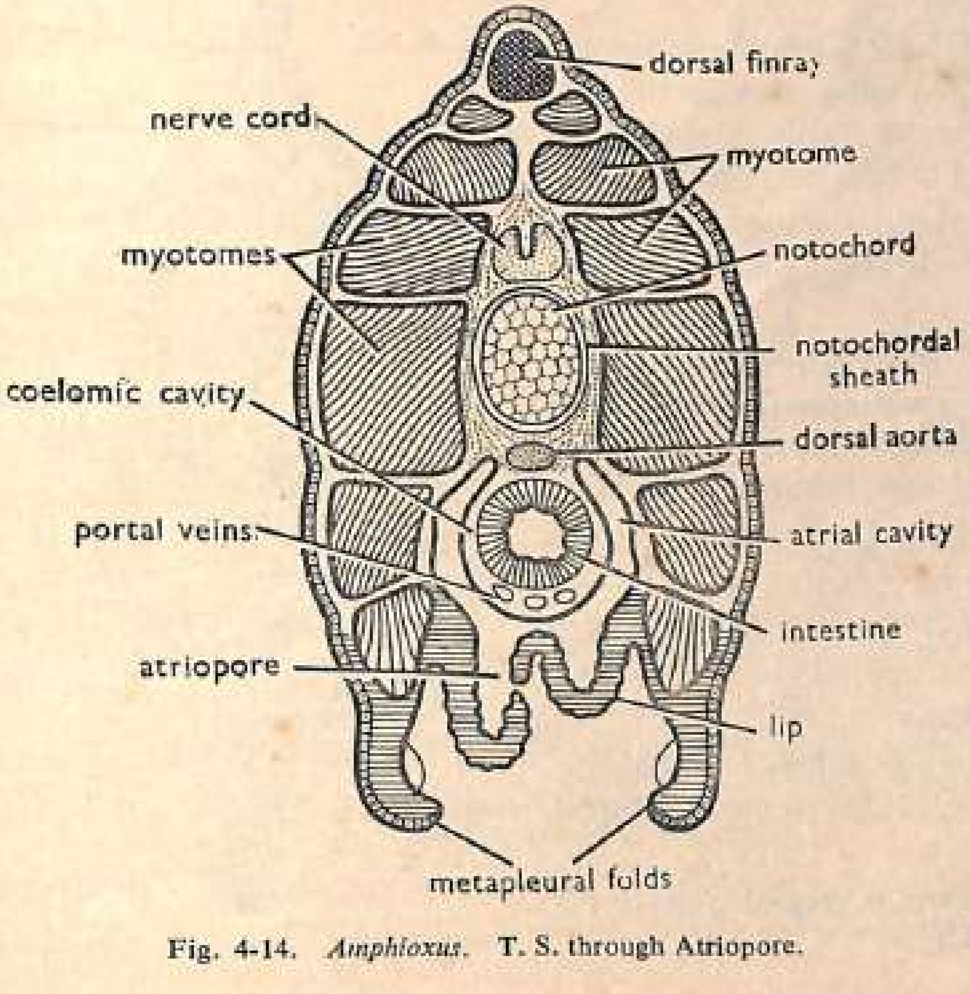


Fig. 4-14. *Amphioxus.* T. S. through Atriopore.

Comments :

(1) The animal narrows towards the posterior region and hence T. S. passing through atriopore shows smaller section. In the section **body wall** layers, **nerve cord, notochord,** and atriopore are seen.

(2) **Body wall** comprises of thin **cuticle**, single-layered thin **epidermal** cells and segmental muscles. The **myotomes** and myocommata alternate. (*For details of body wall layers see T. S. of Amphioxus through the oral hood.*)

(3) The dorsal fin ray is present below the epidermis.

(4) The **nerve cord** is found below 2 or 3 myotomes in the middle. It contains neurocoel.

(5) The **notochord** with notochordal sheath and vacuolated chordal cells is present below the nerve cord.

(6) The dorsal aorta is also found beneath the notochord.

(7) The intestine shows smaller diameter and is composed of endodermal cells. Intestine is surrounded by coelomic and atrial cavities.

(8) In the coelomic cavity below the intestine there are a few cut portions of the portal veins.

(9) The atrial cavity surrounds coelom and opens ventrally by distinct **atriopore**, situated in front of the ventral fin.

(10) The two metapleural folds are distinctly seen.

Identification—*By renal paplliae.*

[15] AMPHIOXUS—T.S. of the Anal Region

Comments :

(1) As the body narrows posteriorly, the T.S. passing through the anal region shows smaller diameter and it tapers at both the ends.

(2) The section shows **body** wall layers, **nerve cord, notochord, intestine** and **anus.**

(3) Body wall is composed of **cuticle, epidermis** and **myotomes.** (*For details see T.S. Amphioxus through the oral hood.*)

(4) The dorsal fin ray is present below the pointed epidermis dorsally.

(5) The nerve cord is found below dorsal fin ray and first myotome. It has central canal.

(6) The **notochord** is found beneath the nerve cord. It has vacuolated **chordal** cells.

(7) Dorsal aorta is present beneath the notochord.

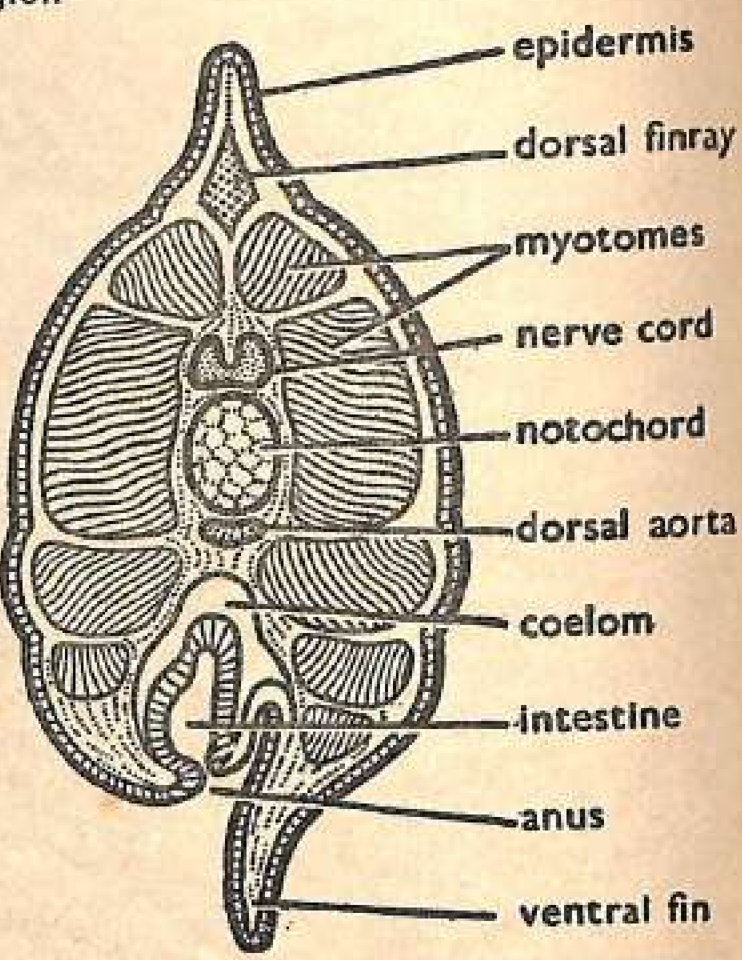


Fig. 4-15. *Amphioxus*. T.S. through anal region.

(8) The coelomic cavity enclosing the intestine is reduced.

(9) Intestine opens to the exterior by the anus.

(10) The ventral fin is pointed in section.

Identification—*By anal pore.*

[16] AMPHIOXUS—T.S. through Caudal Region

Comments :

(1) The section through caudal region is somewhat smaller in size and without any opening.

(2) **Body wall** is composed of **cuticle**, single-layered **epidermis** and **myotomes**. (*For details of body wall see T.S. Amphioxus through the oral hood.*)

(3) The dorsal fin ray is found at the base of dorsal fin below the epidermis.

(4) The **nerve cord** with neurocoel lies below the dorsal fin ray.

(5) The **notochord** with vacuolated chordal cells is found below the nerve cord. It is a supporting rod.

(6) The **caudal** artery and **caudal vein** appear below the notochord.

(7) The artery is found dorsal to the vein.

(8) The alimentary canal is absent.

(9) The atrial cavity, coelom and metapleural folds are absent.

(10) The caudal fin with fin ray is present posteriorly.

Identification—*By the absence of any opening.*

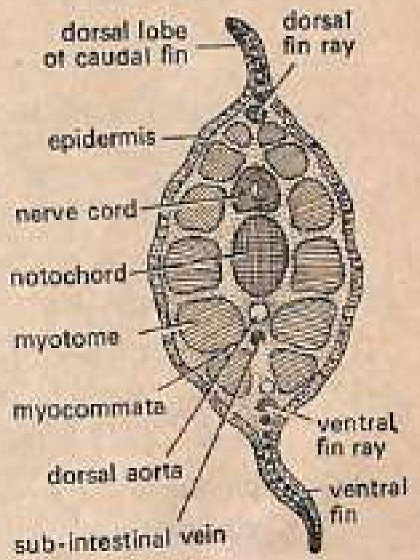


Fig. 4-16. *Amphioxus* T.S. through caudal region.

B. CYCLOSTOMATA

[17] AMMOCOETE LARVA—Whole Mount (Borax carmine stained)

Comments :

(1) It is one of the stages in the development of **lamprey.** The egg develops into **ammocoete larva,** which is a tiny transparent creature in the beginning and later on becomes opaque, 170 mm. long eel-like fish. It lies buried in mud.

(2) The general **body form is eel-like.**

(3) The **mouth** or **buccal** cavity is surrounded by **upper and lower lips**, having number of **buccal tentacles** or **oral cirri.**

(4) **Velum** is found at the posterior end of the buccal cavity followed by the pharynx.

(5) **Pharynx** has 7 pairs of **gill slits**. **Gill arches** and **gill lamellae** lie in the wall of these pouches. Ventrally pharynx contains double strand of mucus-secreting cells called as **endostyle** which would form **thyroid** gland of the adult.

(6) **Head** contains median nostril, **eyes** on sides and an **auditory organ.**

(7) The larva contains **median fin** which forms continuous **dorsal** and **caudal fin.** Ventrally median fin forms **ventral fin.**

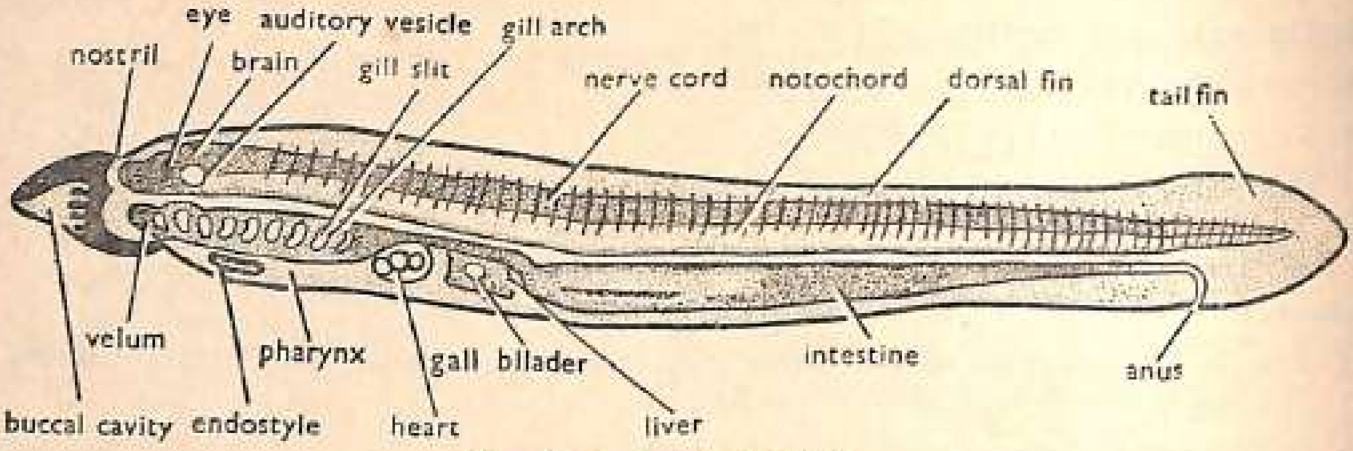


Fig. 4-17. *Ammocoete* larva.

(8) The **nerve cord** with anterior **brain divisions** extends anteroposteriorly along the notochord.

(9) Notochord extends along the entire length of the body.

(10) **Myotomes** are segmentally arranged.

(11) **Heart** lies ventrally posterior to the pharynx and has 3 chambers.

(12) **Pronephros** is seen above the heart.

(13) **Digestive system** after pharynx consists of **oesophagus, wider intestine, anal opening, liver** and **gall bladder**.

(14) Ammocoete larva shows intermediary characters between Cephalochordata and Cyclostomata.

Identification—*By 7 pairs of gill slits.*

[18] AMMOCOETE LARVA—T.S. of the Branchial Region

Comments :

(1) T.S. passing through **branchial region** shows distinct **gill lamellae** along with nerve cord and notochord, etc.

(2) **Body wall** is composed of **epidermis, dermis** and **musculature**. The muscles comprise of thick **myotomes**, separated by **myocommas**.

(3) **Nerve cord** lies just above the notochord.

(4) **Notochord** is surrounded by the notochordal sheath and vacuolated chordal cells.

(5) Below notochord is wide-lumened **pharynx**. It contains several gill lamellae.

(6) On dorsal side of the pharynx is dorsal **aorta** and **mid-dorsal cartilage**, while on ventral side is **thyroid involutions**.

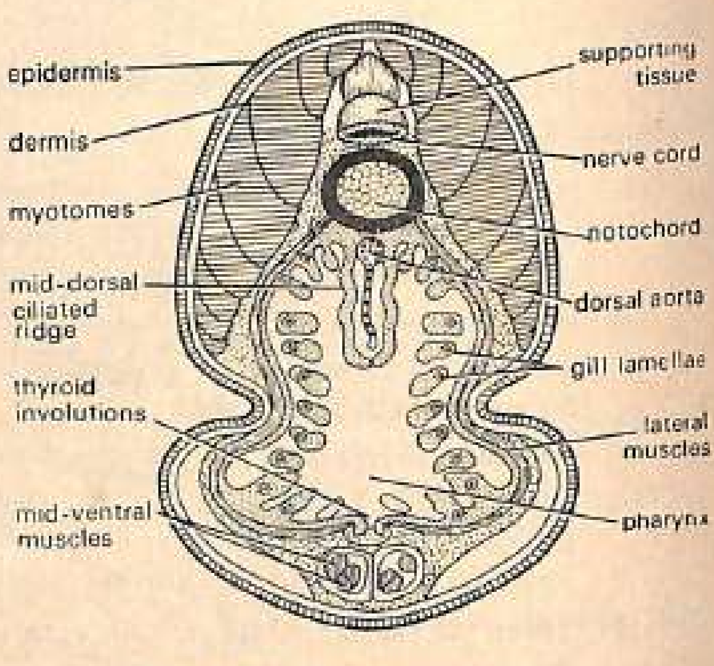


Fig. 4-18. *Ammocoete* larva. T.S. branchial region.

(7) Below thyroid involution bundles of mid-ventral muscles are seen.

(8) Pharynx also contains **velum, ciliated bands** and **endostyle.**

(9) **Endostyle** in larval condition secretes mucus but during metamorphosis it develops into **thyroid** gland, which contains **iodine** vesicles.

(10) Pharynx performs both nutritive and respiratory functions.

Identification—*By mid-dorsal ciliated ridge.*

[19] AMMOCOETE LARVA—T. S. of the Intestine

Comments :

(1) T. S. passing through the intestine shows usual parts of the body wall, **nerve cord, notochord, muscles** and **intestine.**

(2) **Body wall** is composed of **epidermis, dermis** and **myotomes,** which are especially developed on dorsal side.

(3) The supporting tissue and **nerve cord** lie close together.

(4) The **vacuolated notochord** is surrounded by notochordal sheath.

(5) The **intestine** is ventrally situated. It is lined by **endodermal columnar cells.**

(6) On ventral side intestinal epithelium is raised to form **typhlosole,** which increases absorptive surface.

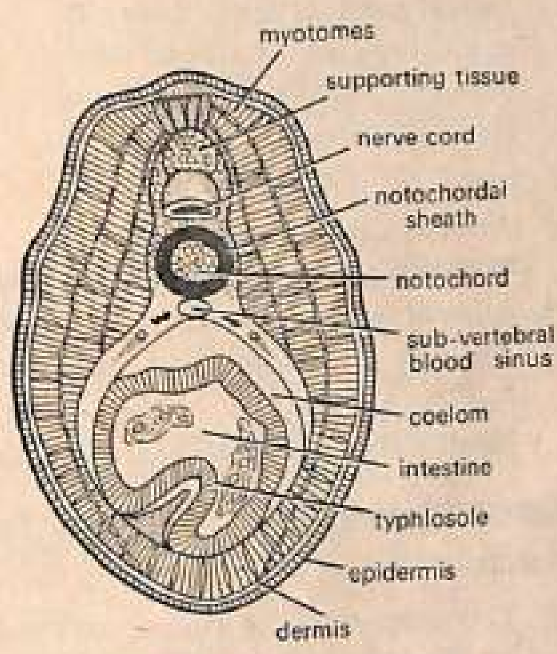


Fig. 4.19. *Ammocoete* larva. T.S. intestine

(7) Sub-vertebral blood sinus is found below the notochord.

(8) **Intestine** is surrounded by coelomic cavity lined by coelomic epithelium.

Identification—*By intestine and typhlosole.*

[20] AMMOCOETE LARVA—T. S. of the Caudal Region

Comments :

The section is smaller in size. It contains the same body-wall layers as in T. S. of the intestine. There is no other visceral structure except notochord, nerve cord, supporting tissue and muscles.

[21] PETROMYZON—T. S. of the Branchial Region

Comments :

(1) The T. S. passing through the above region shows body-wall layers, prominent gill lamellae along with muscles, **nerve cord, notochord** and other visceral structure.

(2) **Body wall** is composed of **epidermis** made up of **stratified squamous epithelium,** which is sometimes covered with polyhedral cells, **dermis** and **musculature.** Epidermal cells may be mucus-secreting cells, granular cells and club cells.

(3) **Dermis** is made up of a dense connective tissue of compact fibres.

(4) **Musculature** comprises of thick **myotome** bundles and **myosepta** or **myocommata.**

(5) The cut **notochord** is composed of vacuolated cells covered by notochordal sheath.

(6) Above notochord is **nerve cord** and **adipose tissue**, which forms fat column.

(7) **Dorsal aorta** is found below the notochord and is followed dorso-ventrally by the **oesophagus**, **respiratory** tube and ventral aorta.

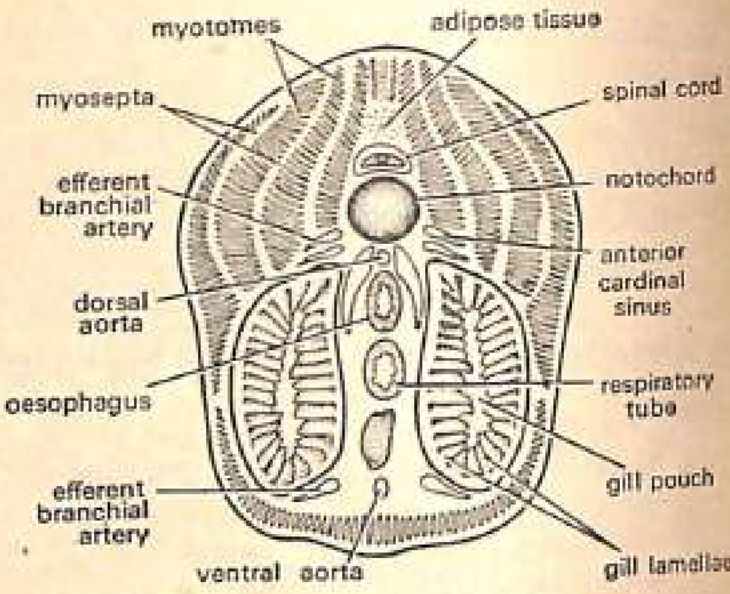


Fig. 4-21. *Pteromyzon*. T. S. branchial region.

(8) **Anterior cardinal sinus, efferent branchial artery** are found on the sides of the dorsal aorta in tandem position.

(9) **Afferent branchial** artery is found on each side of the ventral aorta.

(10) The two **gills** consisting of gill **lamellae** occupy large space in the ventral half of the section.

Identification—*By the large pharynx with gill pouches.*

[22] PETROMYZON—T. S. of the Trunk Region

Comments :

(1) This section can be at once recognized by the presence of various visceral organs.

(2) The above section contains **body-wall** layers, **nerve cord, notochord, kidney, gonads** and **intestine,** etc.

(3) **Body wall** comprises of polyhedral cells, stratified **squamous epithelium, dermis** and **musculature**. Epidermal, cells may be **mucus** secreting cells, **granular** cells and **club** cells.

(4) Dermis is made up of a dense connective tissue of compact fibres.

(5) **Myotomes** separated by **myocommata** are very distinct.

(6) The anterior **dorsal fin** is supported by **cartilaginous radials** arranged in a single series. Some fin muscles are also seen in the section.

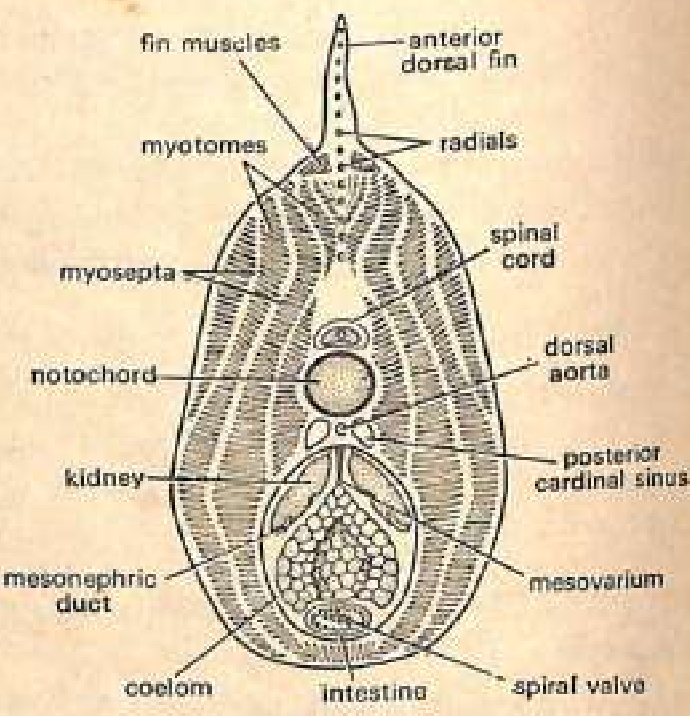


Fig. 4-22. *Petromyzon*. T. S. trunk region.

(7) **The vacuolated notochord** is composed by notochordal tissue covered by notochordal epithelium, which with its basement membrane forms **elastic interna** and a thin black **elastic interna**.

(8) Above notochord is **nerve cord**.

(9) Also note posterior cardinal veins, **dorsal aorta** below notochord, and two kidneys with mesonephric duct.

(10) The gonad (ovary) is suspended from dorsal body wall by **mesovarium**. The **intestine** with spiral valve is also seen below ovary. **Coelom** is bounded by **splanchnopleure** and **somatopleure.**

[23] PETROMYZON—T. S. of the Tail Region

Comments :

(1) The section is smaller in outline.

(2) Body wall is composed of **epidermis, dermis** and **muscles.** (*For details of body wall layers* see *T. S. Petromyzon through branchial region.*)

(3) The dorsal and ventral lobes of the **caudal fin** are supported by cartilaginous **radials.**

(4) **Spinal cord, notochord, caudal artery,** and **caudal vein** are seen in the middle of the section.

(5) The **myotomes** and **mysosepta** are distinct.

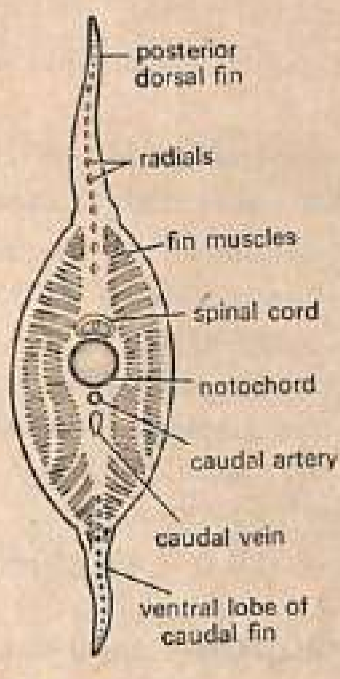


Fig. 4-23· *Petromyzon.* T. S. tail region.

C. FISHES

SCOLIODON—Hand cut section (T. S.)

Transverse sections are prepared from specimens that have been preserved and hardened in formalin. With the help of a **Butcher's knife** or sharp razor, cut the hardened specimen through eye region, olfactory region, branchial region, stomach and liver region, intestinal region, pelvic fin region and caudal region.

[24] SCOLIODON—Hand cut T. S. of the Eye Region

Comments :

(1) This section can at once be recognized by **prominent eyes** on the sides. Section is oval.

(2) The entire section is covered by the skin, which contains several **placoid** scales and small denticles.

(3) Eyes are found on either side of the section. Each eye contains **cornea** and **lens.** Eye is innervated by thick optic nerve.

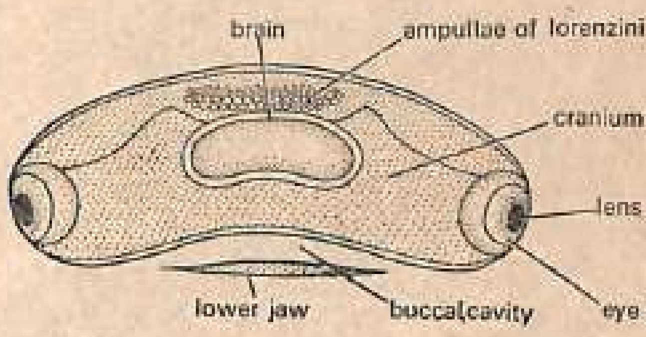


Fig. 4-24. *Scoliodon.* Hand cut T. S. Eye region.

(4) The interior of the section is occupied by the cartilaginous **cranium.**

(5) In the middle of the section is brain.

(6) On the ventral side lower jaw is also seen.

(7) On the dorsal side several rounded sensory ampullae of lorenzini are seen.

(8) **Myotomes** are absent.

[25] SCOLIODON—Hand cut T.S. of Olfactory Region

Comments :

(1) The section is somewhat oval in outline.

(2) It is covered by skin on all sides which is of several placoid scales.

(3) The middle of the section has cranium and brain.

(4) On either side of the section various cut parts of the internal ear like ampullae, semicircular canals, sacculus lagena and utriculus are seen.

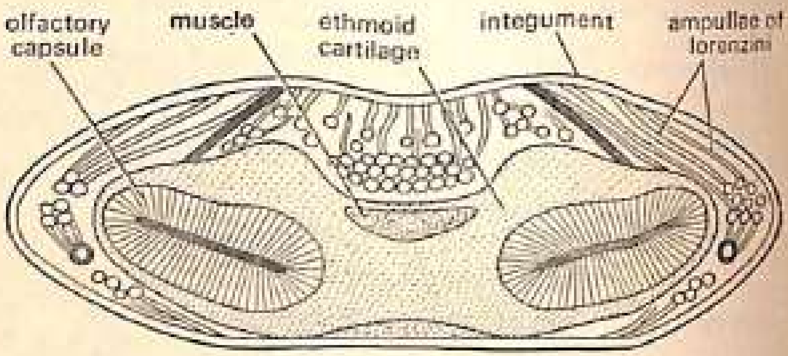


Fig. 4-25. *Scoliodon*. Hand cut T.S. of olfactory region.

(5) On ventral side, the pharynx, hyoid and branchial arches are also seen.

[26] SCOLIODON—Hand cut T.S. of the Branchial Region

Comments :

(1) T.S. passing through above region shows body wall layers, myotomes, nerve cord, notochord, oesophagus, heart and bronchii or gills.

(2) The section is covered by pigmented skin or integument from all sides. Skin is composed of epidermis and dermis.

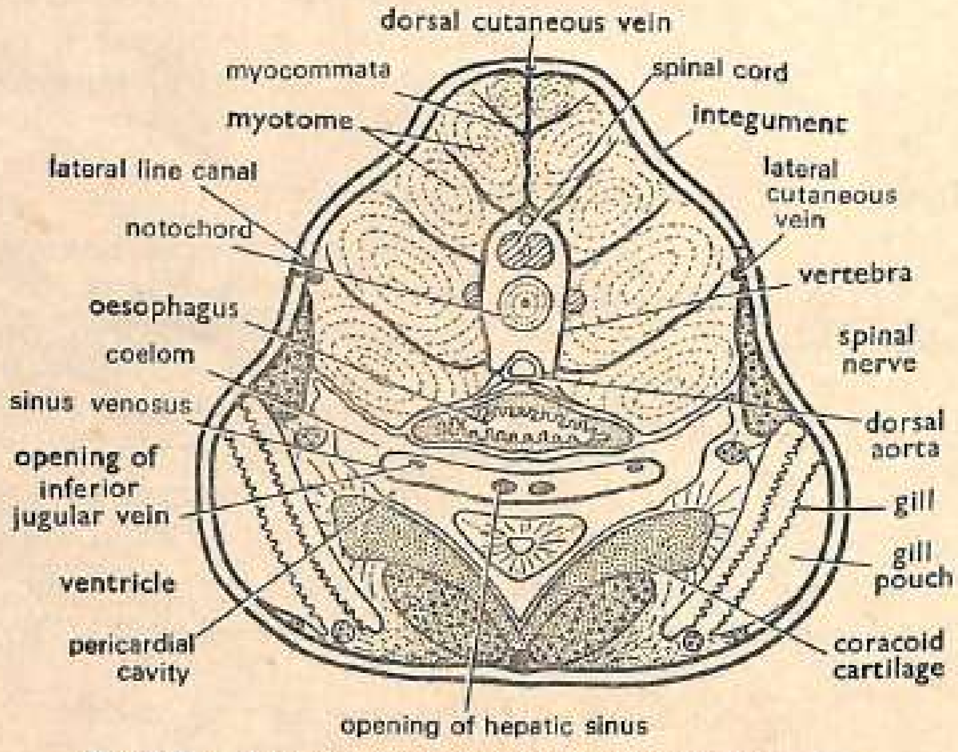


Fig. 4-26. *Scoliodon*. Hand cut T.S. of the branchial region.

(3) The skin contains several **dermal placoid** scales.

(4) The dorsal half of the section has thick segmental muscle bundles **myotomes,** separated by myocommata. The myotomes are concentrically arranged.

(5) In the middle of the musculature **cartilaginous vertebra** is found.

(6) The **spinal cord** with **neurocoel** is found in the vertebra.

(7) **Notochord** is found just below the nerve cord.

(8) **Dorsal** aorta is situated just beneath the vertebra.

(9) **Oesophagus** with thick walls and villi is found just below the dorsal aorta. Beneath oesophagus is **pericardial** cavity enclosing **sinus venosus** and the thick-walled ventricle. Below pericardium is the **coracoid cartilage**.

(10) The **gills** with gill pouches are found on the side of pericardium and coracoid cartilage. Gills occupy entire side ventral halves. Various cut blood vessels are also seen.

[27] SCOLIODON—Hand cut T.S. of Stomach and Liver Region

Comments :

(1) T.S. passing through above region shows body wall layers, musculature, spinal cord, nerve cord, **stomach** and **liver**. Section is roughly triangular.

(2) Body consists of skin and musculature. **Skin** is made of **epidermis** and **dermis**. Several **dermal placoids** are found in the highly pigmented integument.

(3) The **myotomes** are thick muscle bundles, arranged concentrically and separated by the **myocommata**. Practically entire dorsal half of the section contains segmental myotomes.

(4) In the central axis there is a median **vertebra**.

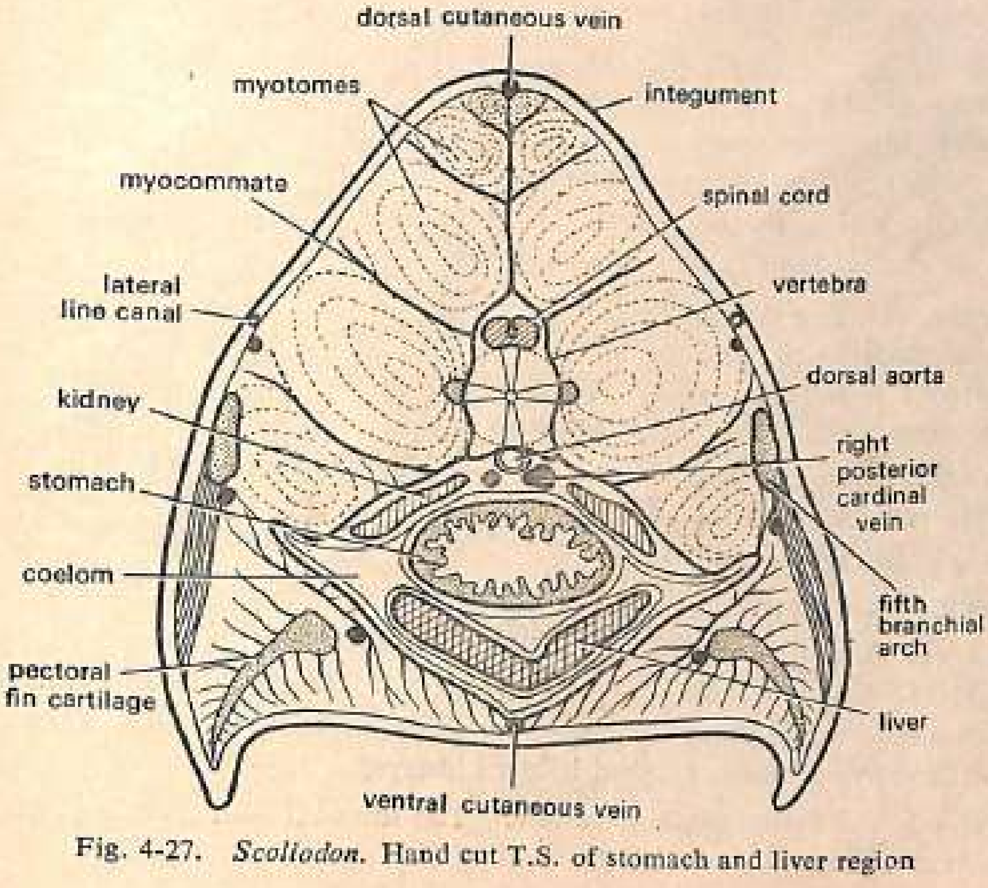


Fig. 4-27. *Scoliodon*. Hand cut T.S. of stomach and liver region

(5) **Nerve cord** with neurocoel is found in the vertebra.

(6) **Notochord** is found just beneath the nerve cord.

(7) **Dorsal aorta** is found just below the vertebra.

(8) The ventral half of the section has a spacious **coelomic** cavity, lined by visceral and peritoneal layers and containing visceral organs.

(9) Thick walled **stomach** with internal **villi** is found in the middle. **Kidneys** are found on the sides of the **stomach,** while **liver** is found below the stomach.

(10) **Cartilage** of **pectoral fin,** cut portions of **cutaneous** veins, fifth **branchial arch** and lateral line canal are also seen in the section.

Identification—*By stomach.*

[28] SCOLIODON—Hand cut T.S. of the Intestinal Region

Comments :

(1) T.S. passing through above region shows body wall layers, nerve cord, notochord, kidneys, gonads, **scroll valve** in the **intestine** etc. Section is pointed dorsally.

(2) Body wall consists of **epidermis, dermis** and musculature.

(3) **Skin** with dermal **placoid scales** covers the section from all sides.

(4) **Myotomes** arranged concentrically and myocommata occupy more than the dorsal half of the section on each side.

(5) **Vertebra** containing nerve cord or **spinal cord** and **notochord** is found in the median axis.

(6) **Dorsal aorta** is found just below the vertebra.

(7) **Coelomic** cavity is reduced. It accommodates viscera.

(8) **Kidneys** are found below dorsal aorta. Cut portions of the **seminal vesicle** and **testes** with spermatozoa are found below kidneys.

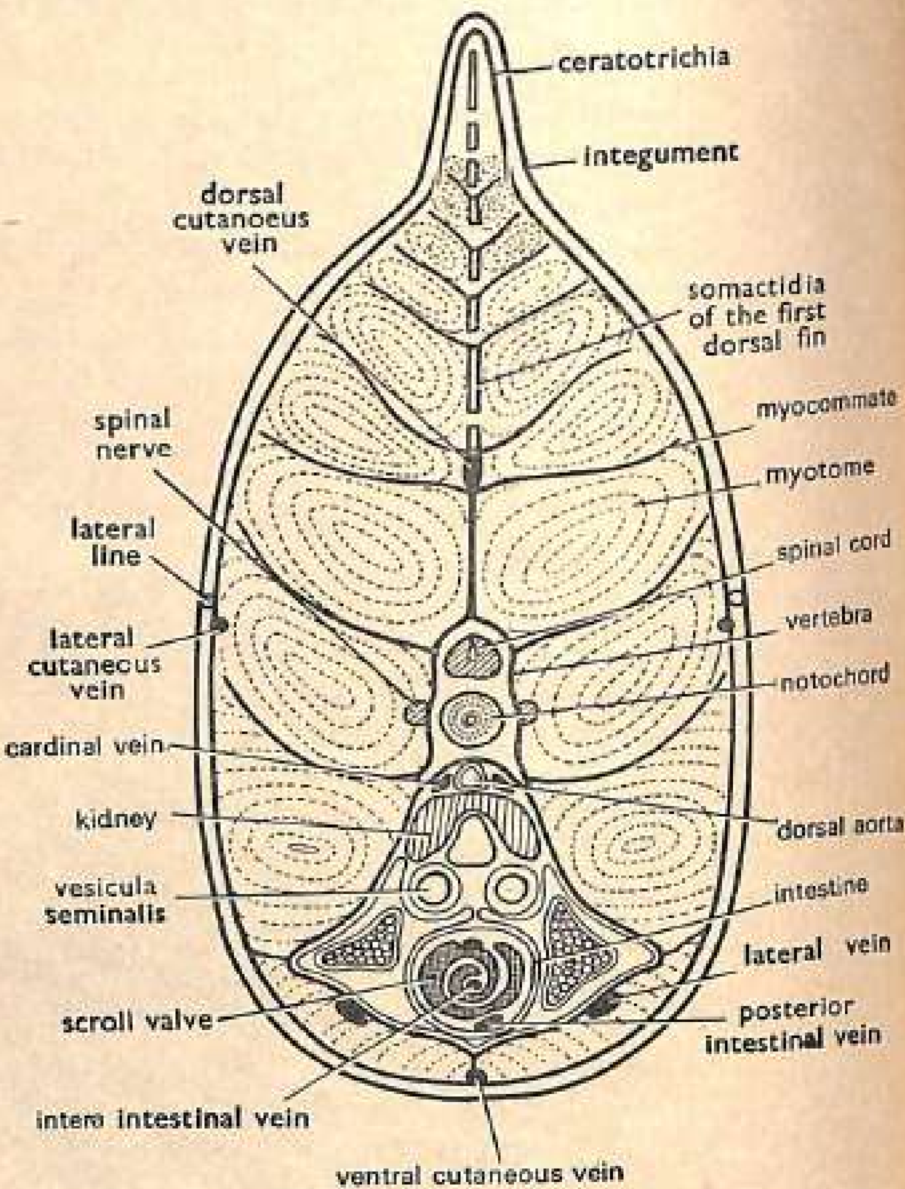


Fig. 4-28. *Scoliodon.* Hand cut T.S. of the intestinal region.

(9) **Intestine** is found below seminal vesicle. The internal fold forming anti-clockwise **scroll valve** is very distinct.

(10) Various cut blood vessels, spinal nerves and lateral lines are also seen in the section.

Identification—*By the scroll valve in the intestine.*

[29] SCOLIODON—Hand cut T.S. of the Base of the pelvic fin of Male and Female

Comments :

(1) T.S. passing through the above region shows body-wall layers, nerve cord, notochord, kidney, **uterus** in females and **seminal vesicles** in males etc.

(2) Body wall is composed of skin and musculature.

(3) Skin covers the section from all sides. It consists of **epidermis** and **dermis.** Various dermal placoid scales are found in the skin.

(4) **Musculature** consists of concentrically arranged **myotomes** separated by **myocommata** and they occupy the entire section, except some central area for viscera.

(5) **Vertebra** is found in the central axis. It encloses **spinal cord** and **notochord** in tandem position.

(6) **Coelomic cavity** is very much reduced.

(7) Dorsal aorta is found just beneath the vertebra.

(8) **Posterior cardinal vein, kidney** and **ureter** are found below dorsal aorta, one after the other, towards posterior side.

(9) In **female** *Scoliodon* the 2 uterii fuse together forming a single **uterus,** which lies below the ureters.

(10) In male *Scoliodon* two seminal vesicles lie below the ureters.

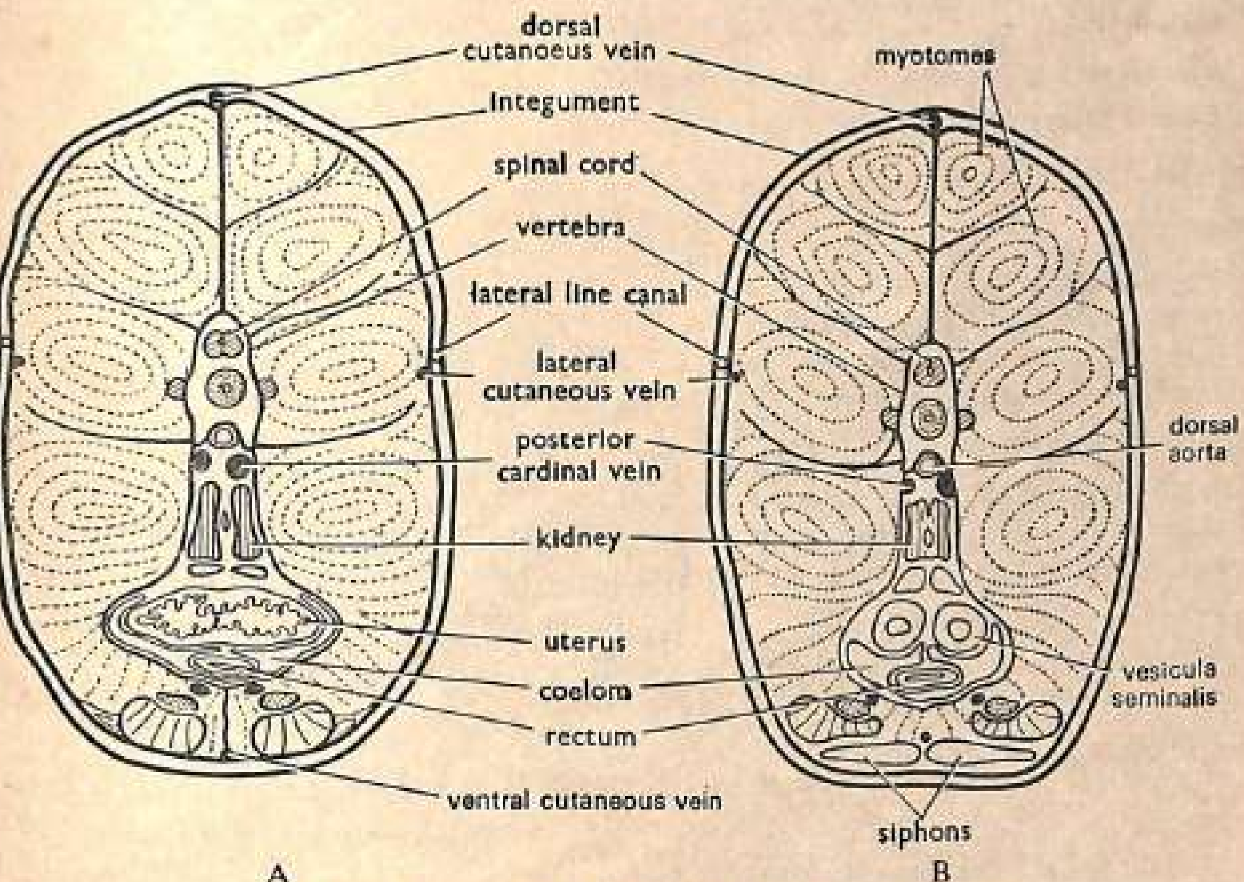


Fig. 4-29. *Scoliodon.* Hand cut T.S. of the pelvic region.
A—Female. B—Male.

(11) Various cut portions of blood vessels, cartilage of pelvic fin and rectum are also seen in the section.

Identification—*By uterus in female and seminal vesicles in male.*

[30] SCOLIODON—Hand cut T.S. of the Caudal Region

Comments :

(1) T.S. passing through the caudal region shows body wall, caudal vertebra and muscle bundles. No other structure is found in this region.

(2) Body wall is composed of **skin** and **musculature**.

(3) **Skin** or **integument** consists of epidermis and dermis. Skin has several dermal placoid scales.

(4) The concentrically arranged **myotomes** separated by myocommata occupy almost entire space of the section.

(5) Vertebra is found in sub-equatorial mechanical axis.

(6) **Nerve cord** and **notochord** are enclosed in the vertebra.

(7) **Caudal vein** is found below the **caudal artery**.

(8) **Caudal artery** is found below the vertebra.

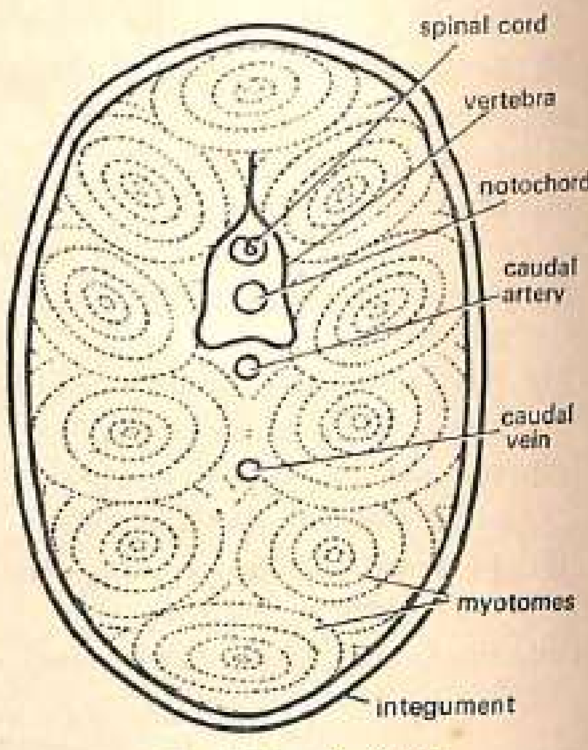


Fig. 4-30. *Scoliodon.*
Hand cut T.S. of the caudal region.

[31] FISH—Cycloid Scales

Comments :

(1) **Cycloid scales** are found in **carps** (teleost) and **lungfishes** (dipnoi). They are located in the dermal pockets and possess lines of growth.

(2) Each **cycloid** scale is roughly circular in outline without pulp cavity and with free and smooth border.

(3) The scales covering lateral line are frequently perforated permitting the passage of small connectives of **lateral line to outside.**

(4) **Cycloid** scales are derived form of **ganoid scales** in which **ganoin**, **cosmine** and **bone** cells are lost.

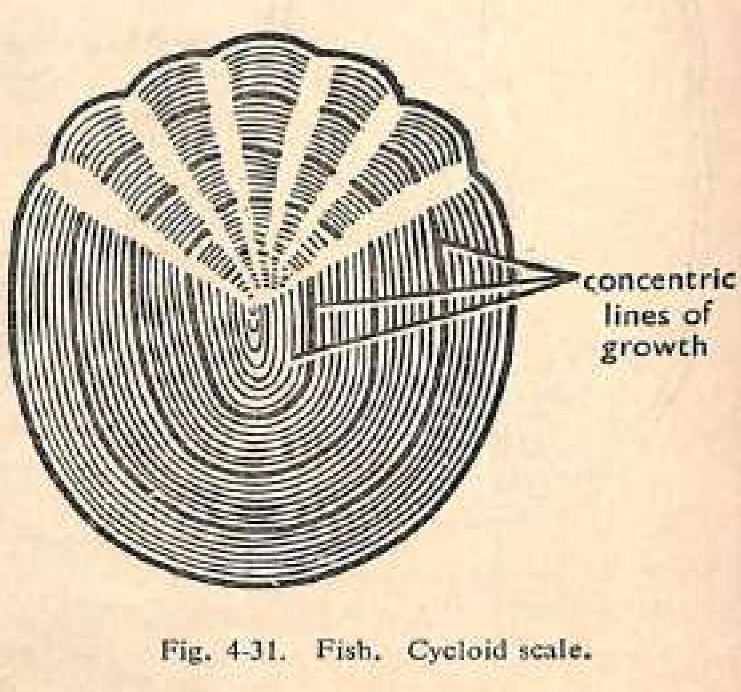


Fig. 4-31. Fish. Cycloid scale.

(5) The **scales** are soft, arranged lengthwise in diagonal rows.

[32] FISH—Ctenoid Scales

Comments :

(1) **Ctenoid** scales are commonly found in most **teleost** and **actinopterygian** fishes.

(2) They are thin, soft and dermal translucent plates.

(3) They are composed of underlying fibrous layer covered by bone-resembling layer.

(4) They contain concentric rings, representing **lines of growth.**

(5) The lines of growth vary in different specimens.

(6) **Ctenoid** scales do not contain **ganoin.**

(7) Each scale is embedded in a small dermal pocket.

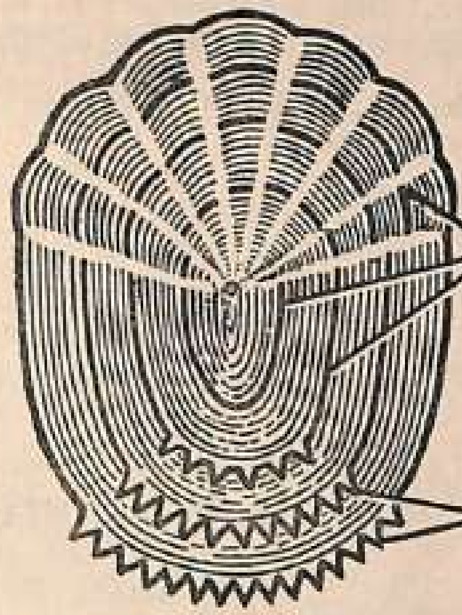


Fig. 4-32. Fish. Ctenoid scale.

(8) The scales are obliquely arranged so that posterior end of one overlaps the anterior end of the following scales.

(9) Basal end is scalloped and free edge bears numerous comb-like projections.

(10) Ctenoid scales are derivatives of ganoid scales in which **ganoin**, cosmine layers and bone cells are lost. The pulp cavity and dentine are entirely absent.

[33] FISH—Placoid Scales

Comments :

(1) With very few exceptions, **placoid scales** are abundantly found in dermis of **elasmobranch** fishes.

(2) The placoid scales are arranged in regular oblique rows. They are dermal in origin and cover entire surface of the body, forming dermal **exoskeleton** of the sharks.

(3) Each **scale** is composed of a **basal bony** plate embedded in the dermis, from which a spine projects upwards and points posteriorly.

(4) The basal plate is formed of a trabecular calcified tissue.

(5) The **spine** is composed of **dentin** covered by a hard material, **vitrodentine.**

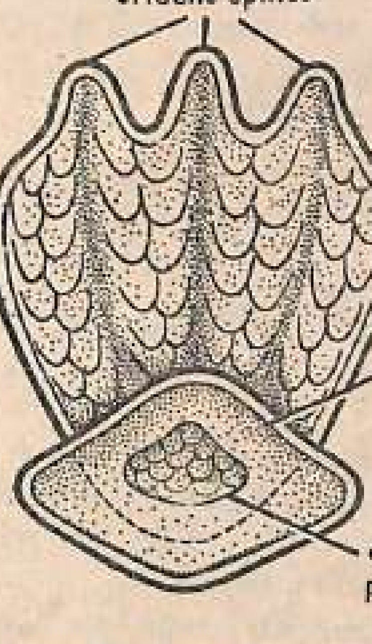


Fig. 4-33. Fish. Placoid scale.

(6) The **placoid** scale contains a **pulp cavity** in spine.

(7) The pulp cavity contains **odontoblasts,** dentine forming cells, blood capillaries, nerves and lymph channels.

(8) The general similarity in structure of placoid scales to teeth of higher forms should be apparent. Both are considered to be remnants of bony armour of such primitive vertebrates as **ostracoderms** and certain **placoderms**.

Identification—*By indent spines.*

[34] FISH—Ganoid Scales

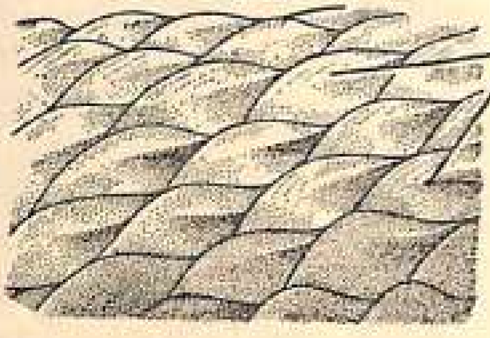


Fig. 4-34. Fish. Ganoid scales.

Comments :

(1) **Ganoid scales** are found in primitive ray-finned fishes such as *Polypterus* and gar pikes.

(2) The scales are covered with a hard, shiny and translucent material of mesodermal origin called as **ganoin.**

(3) Ganoid scales fit together like tiles and are arranged in diagonal rows.

(4) The scales are dermal in origin.

(5) Each scale consists of a bony base, coated by shining substance called as **ganoin.**

D. AMPHIBIA

[35] FROG—V.S. of the Skin

Comments :

(1) Skin covers on all sides and due to amphibious life, skin is thin, tough, slimy, slippery and richly supplied with mucous glands. Vertical section passing through the skin of frog reveals two distinct principal layers—**epidermis** towards outerside and **dermis** towards inside.

(2) **Epidermis** is composed of several epithelial cells, differentiated into two layers. The outermost layer consists of keratinised **stratum corneum**, while inner layer is **stratum germinativum.**

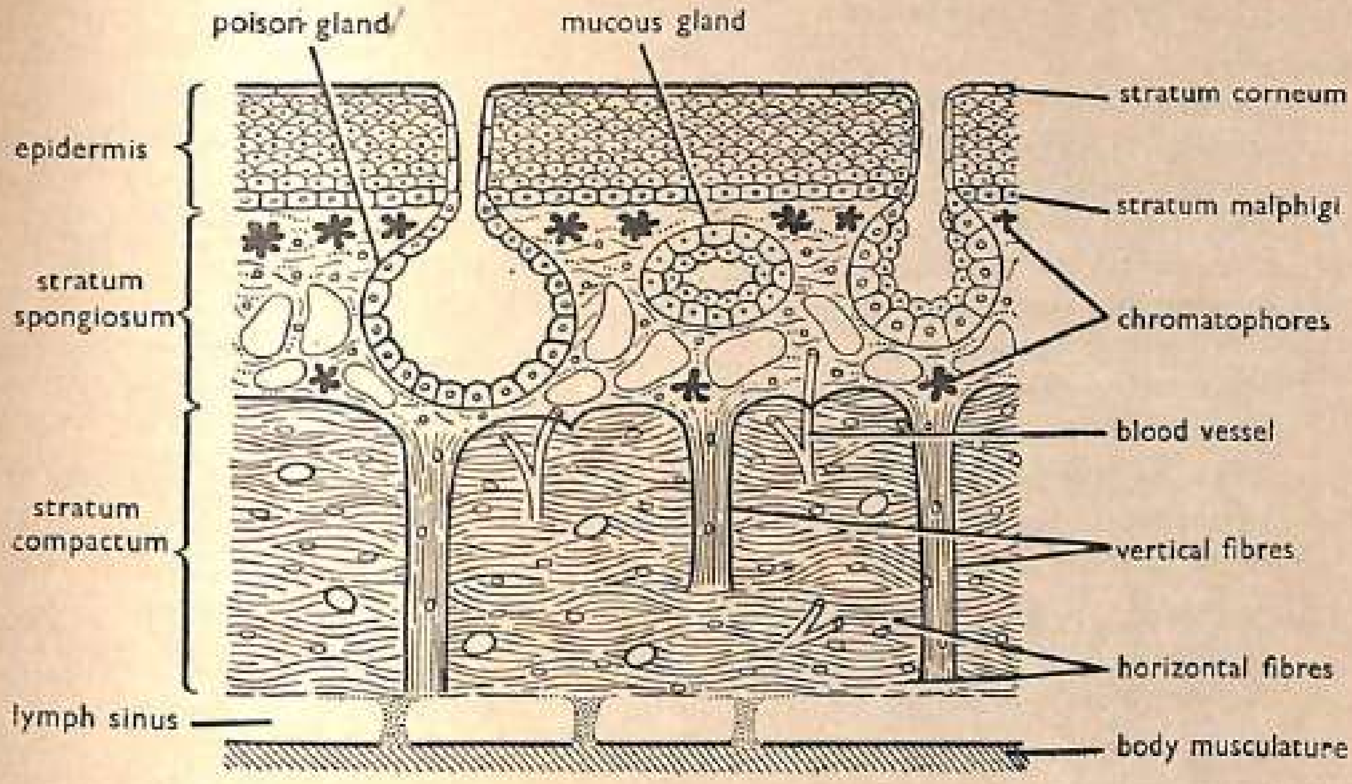


Fig. 4-35. Frog. V.S. skin.

(3) **Stratum corneum** comprises of several stratified layers of cells. Outermost layer is of squamous corneal cells.

(4) **Stratum germinativum** comprises of single layer of **columnar** cells resting on **basement membrane.** These cells divide mitotically and move towards exterior. As these cells move, they become scale-like and contain fibrous protein, called as **keratohyaline.** As cells reach outermost layer, keratohyaline dries and become **keratin,** which forms waterproof layer.

(5) Epidermis contains **mucous glands** and in some species of *Rana* **poison glands** also.

(6) **Dermis** is found just beneath epidermis and is differentiated into two zones. The outer zone is made up of spongy fibres and called as **stratum spongiosum,** while inner zone **stratum compactum** containing dense connective tissue fibres.

(7) Dermis contains nerves, muscle fibres, blood capillaries and chromatophores.

(8) **Chromatophores** are coloured pigments and are of 3 kinds :—
   (a) **Lopohores** contain yellow pigment or xanthophyl.
   (b) **Melanophores** contain black pigment, called as **melanin.**
   (c) **Guanophores** contain white reflecting substance, called as **guanine.**

(9) The contraction and expansion of pigment granules are under **hormonal** control. **Epinephrin** from the **adrenal** gland controls the concentration of granules in the centre, while **intermedus** from pituitary controls the spreading of the granules.

(10) Skin of frog performs various functions, such as **protection, water observant, respiratory, mucus secreting, sensory, excretory** and **swimming.**

Identification—*By mucous glands.*

[36] FROG—T.S. of the Stomach

Comments :

(1) **Stomach** is a broad tube, highly muscularised, having masticatory and digestive function. Histologically stomach is composed of **serosa, musculature, sub-mucosa, muscularis mucosa** and **mucosa**.

(2) The serosa forms the outermost layer. It is derived from **visceral peritoneum** and is composed of flat **squamous** cells, called as **mesothelium.**

(3) **Musculature** consists of **outer longitudinal** and **inner circular** muscle fibres.

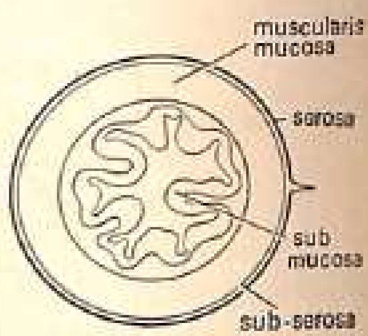


Fig. 4-36. Frog. T.S. stomach (low magnification).

(4) The outer **longitudinal** muscles run longitudinally and are made up of **unstriped** fibres. By the contraction of longitudinal muscles, stomach becomes shortened and the volume of the lumen is widened.

(5) The inner **circular muscles** consist of circular fibres. It forms thick layer than longitudinal fibres. By the contraction of these muscles, stomach increases in its size but the volume of the lumen is reduced.

(6) By alternate contractions and relaxations of longitudinal and circular fibres, the food is pushed backward and is also masticated.

(7) There is a ganglionated **nerve plexus** between longitudinal and circular muscle layers.

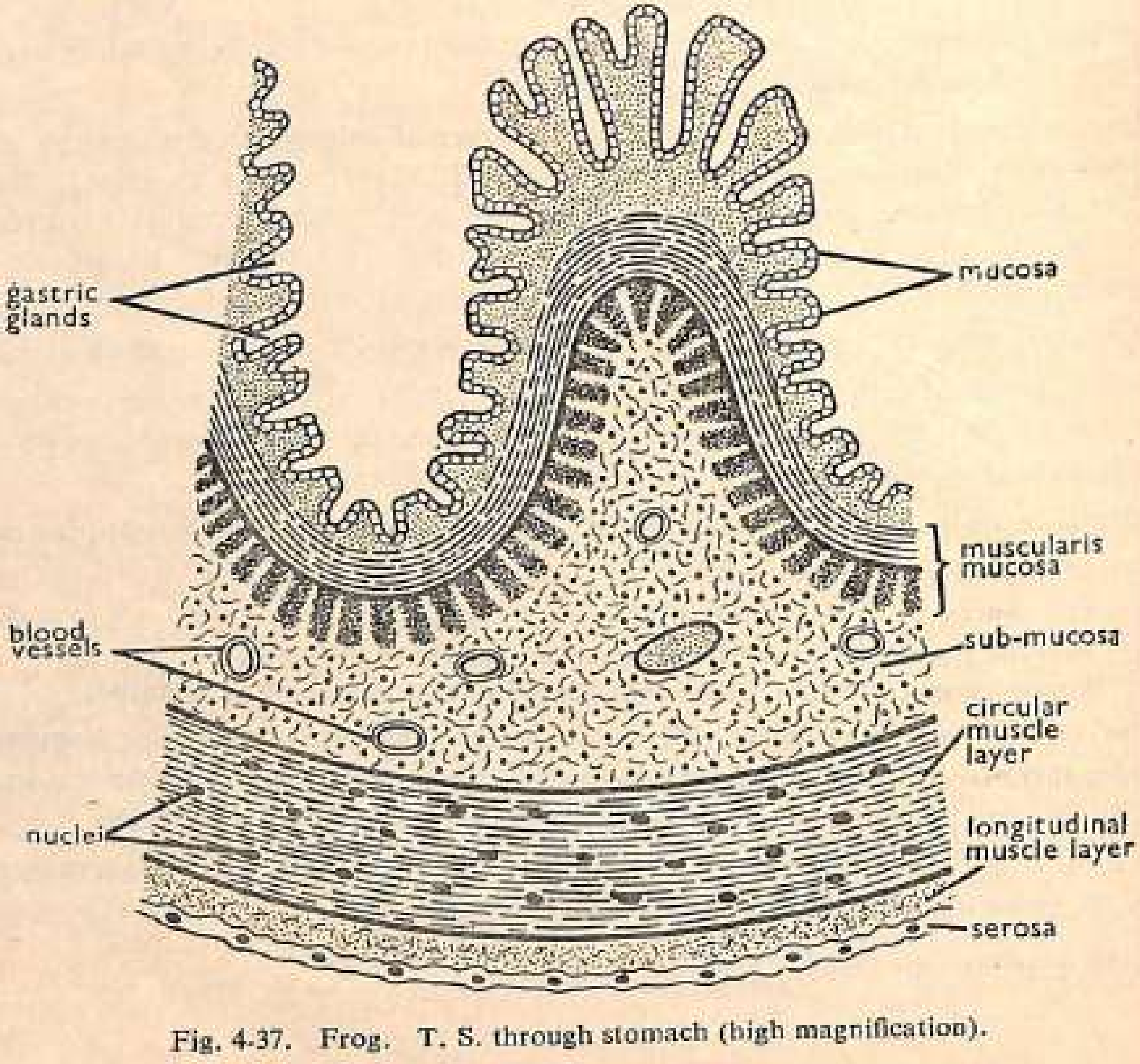


Fig. 4-37. Frog. T. S. through stomach (high magnification).

(8) **Sub-mucosa** is made up of loose **areolar** connective tissue having nerves and blood vessels. It serves to bind loosely **muscularis mucosa** with the muscular coat. It also contains blood vessels and lymphatic vessels.

(9) **Muscularis mucosa** consists of longitudinal and circular layers.

(10) **Mucosa** is the innermost layer thrown into folds or **villi**. Mucosa consists of inner **columnar epithelial** cells, resting on basement membrane and outer **lamina propria.** Mucosa contains **goblet cells**, oxyntic cells (HCl secreting), zymogen cells (pepsin secreting) and mucous cells (mucus secreting).

(11) **Functions**—As soon as food reaches into the stomach, its muscular walls masticate the food; its gastric glands secrete digestive enzymes which hydrolyse the food. Pepsin breaks **peptide bonds** and converts proteins into derived proteins i.e. **peptones** and **proteoses.** HCl kills the bacteria or living food and converts inactive pepsinogen into active pepsin.

[37] FROG—T. S. of Duodenum

Comments :

(1) Histologically duodenum resembles with ileum but its mucosa is peculiar. The section shows serosa, **musculature, sub-mucosa, muscularis mucosa** and mucosa.

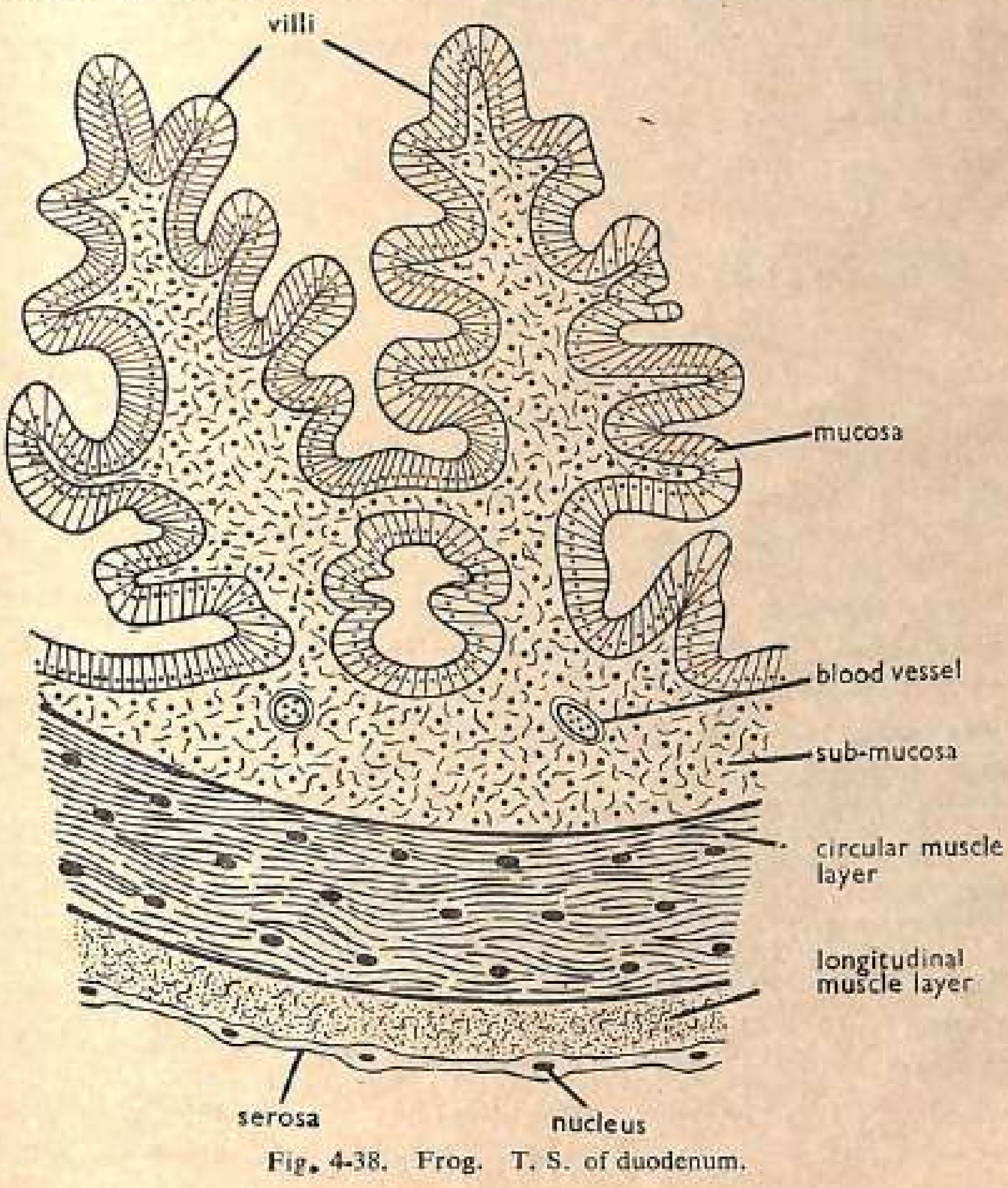


Fig. 4-38. Frog. T. S. of duodenum.

(2) **Serosa** forms outer covering of duodenum. It is derived from the visceral peritoneum and is composed of flat **squamous epithelial** cells, called as **mesothelium**.

(3) The **musculature** or **muscular coat** is composed of two layers of muscular tissue, an outer **thinner longitudinal** and inner thicker **circular.**

(4) The **longitudinal muscles** are composed of unstriped fibers. By its contraction, the duodenal tube is shortened but the volume of its lumen is widened.

(5) **The circular muscles** consist of circular fibers. By their contraction, the duodenal tube increases in size but the volume of its lumen decreases.

(6) Between longitudinal and circular muscles lies a network of lymphatic vessels and nerve fibres.

(7) **Sub-mucosa** is well developed and is composed of loose connective tissue. In it the **blood vessels** and **lacteals** ramify before entering or after leaving the mucous membrane. It also contains nerves.

(8) Mucosa is thrown into irregular and branched villi. The villi are highly branched and form a sort of network and contain **Brnnner's glands** which produce mucus. The crypts of Liaberkühn produce **succus entericus**.

(9) Muscularis mucosa consists of inner circular and outer longitudinal layers.

(10) **Functions**—Duodenum is V-shaped. It encloses pancreas. Secretions from liver and pancreas are poured into the lumen of duodenum. Two **hormones**, **cholecystokinin** and **secretin**, secreted in it, stimulate liver to secrete bile and pancreas to secrete pancreatic juice, respectively. In duodenum food is converted into amino acids and polypeptides, maltose and fatty acids and glycerol.

[38] FROG—T.S. of the Intestine

Comments :

(1) **Intestine** is modified for absorption and hence it is less muscularised. The T.S. passing through it shows **serosa, musculature, sub-mucosa, muscularis mucosa** and **mucosa.**

(2) The **serosa** coat is complete except over part of the duodenum. **Serosa** originates from the visceral peritoneal layer and is composed of flat **squamous epithelial** cells, called as **mesothelium.**

(3) The **muscle coat** or **musculature** contains **outer longitudinal** and **inner circular muscle** layers.

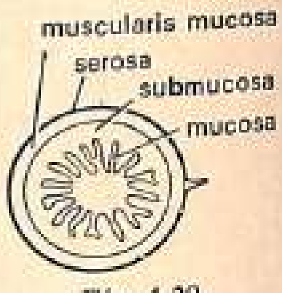


Fig. 4-39.
Frog. T.S. intestine
(low magnification).

(4) The **longitudinal layer** consisting of **unstriped** fibers forms thin layer. The size of the intestine is decreased and the volume of the intestinal lumen is increased by the contraction of the longitudinal layer.

(5) The **circular muscle** fibers form thick layer. When they contract, size of the intestine is increased and the volume of the lumen is decreased.

(6) Between longitudinal and circular layers, a network of **lymphatic** vessels and **plexus myentericus**, consisting of plexus of amyelinated nerve fibres, is found.

(7) **Sub-mucosa** is also well developed, made up of connective tissue and having nerves, lymph spaces and blood vessels.

(8) The **blood** vessels and **lacteals** ramify before or after leaving the mucous membrane. The nerve **plexus** is called as **plexus** of **Meissner.**

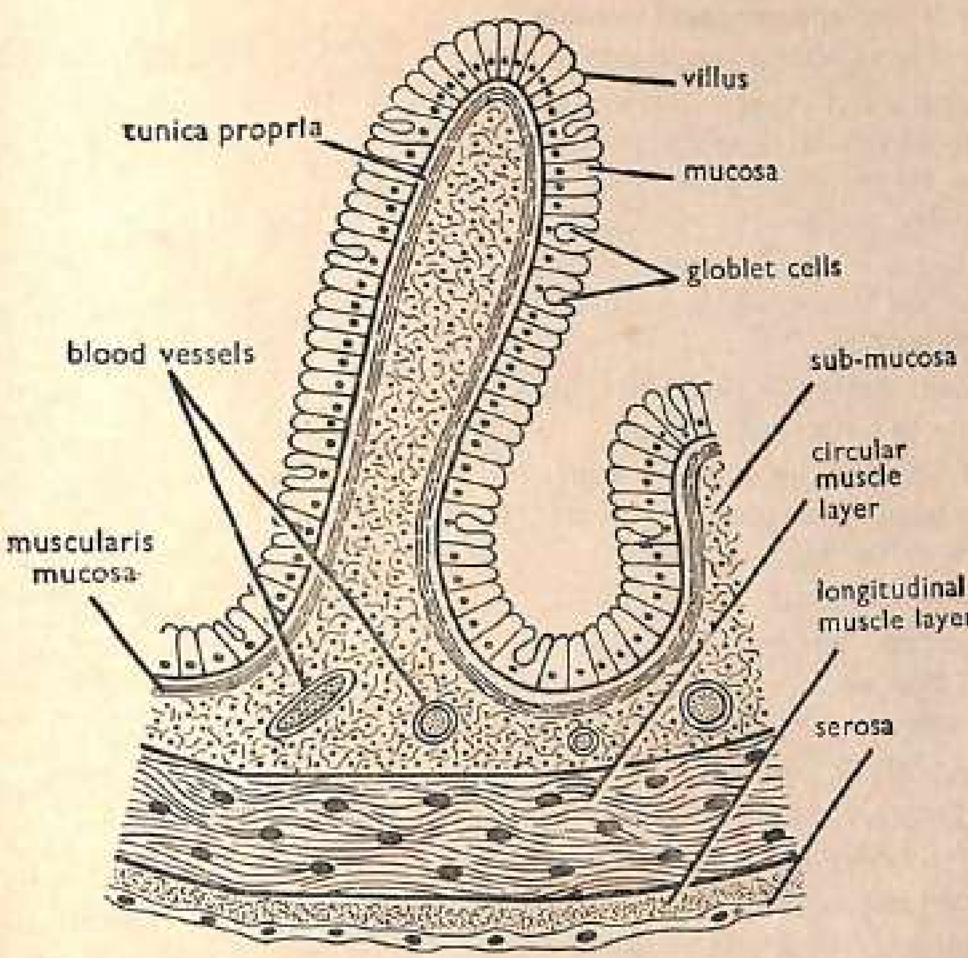


Fig. 4-40. Frog. T.S. of ileum or small intestine (high magnification).

(9) **Muscularis mucosa** is not well developed and contains inner circular and outer longitudinal muscle layers.

(10) **Functions—Mucosa** is thrown into **villi.** It consists of a single layer of columnar epithelial cells, having goblet cells and absorptive cells. The goblet cells secrete mucus, while absorptive cells absorb food material. The intestinal juices are **peptidases, maltose, lipase,** invertase and **lactose**, which hydrolyse the food into sugar, fatty acids and glycerol, glucose and fructose and glucose and galactose respectively.

[39] FROG—T.S. of the Liver

Comments :

(1) Amphibian liver is dark chocolate coloured and large in proportion to the size of the body. The liver of frog contains three unequal lobes but connected with each other. T.S. passing through the liver shows the following histological details.

(2) The **liver** is a solid glandular organ, made up of **polyhedral hepatic lobules** in the form of branched columns, separated from one another by the connective tissue.

(3) Externally liver is covered by serous coat and each **lobule** penetrated by fine network of connective tissue and **sinusoid blood vessels,** called as **hepatic capillaries.**

(4) **The portal** vein, **afferent** blood vessel and **hepatic** artery enter its undersurface, where bile duct passes from the gland. The fine branches from above three form **interlobular** and **intralobular** vessels.

(5) The wall of the **sinuses** contain Kupffer cells of phagocytic nature.

(6) Each hepatic cell contains one or two **vesicular nuclei, fat droplets, pigment granules, ribonucleoprotein, glycogen, mitochondria** and **Golgi bodies.**

(7) The glycogen formation occurs in the middle of the lobule, while peripheral area secretes **bile.**

(8) Large ducts drain bile capillaries and they unite to form hepatic duct.

(9) The bile secreted by liver is stored into a large pear-shaped saccular structure, called as **gall bladder.**

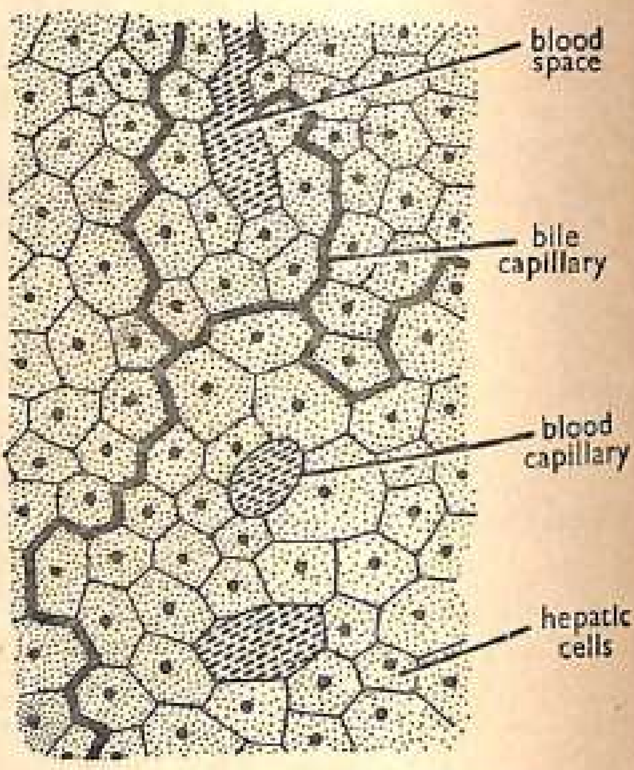


Fig. 4-41. Frog. T.S. of liver.

(10) **Liver** has the following functions—

(a) It secretes bile juice, consisting of **bile salts, bile pigments, cholesterol** and **lecithin**, which act as fat emulsifier.

(b) It stores glycogen, inorganic salts of iron and copper. **Glycogenesis** and **glycogenolysis** take place in liver.

(c) Liver produces **fibrinogen** and **prothrombin**, which are essential components of clotting of blood. It produces **heparin**, which prevents blood clotting.

(d) Liver changes ammonia into urea. Urea synthesis takes place by **ornithine cycle.** This process is also called as deamination.

(e) Liver also controls oxidation of sugar. (f) It is excretory.

(g) In embryonic condition liver produces blood corpuscles.

(h) Various enzymes are synthesized in liver.

(i) Liver also stores and synthesizes **vitamins.**

(J) Liver is a very important organ for metabolism.

[40] FROG—T. S. of Pancreas

Comments :

(1) Pancreas is noteworthy because in amphibians one or more pancreatic ducts open either directly into duodenum or indirectly through bile duct.

(2) Pancreas is a large and yellow-coloured compound tubulo-alveolar gland, situated between duodenum and stomach, and covered with coelomic epithelium.

(3) Histologically it is composed of several **lobules** or **acini**, connected by loose connective tissue.

(4) Each lobule contains bunch of **secretory cells** and a central lumen.

(5) The **cytoplasm** of each lobule is filled with **granules** and in haematoxylin-stained sections outer part is more deeply coloured than the inner, due to concentration of **mitochondria.**

(6) The centre of the acinus communicates with the nearest duct and it secretes digestive enzymes.

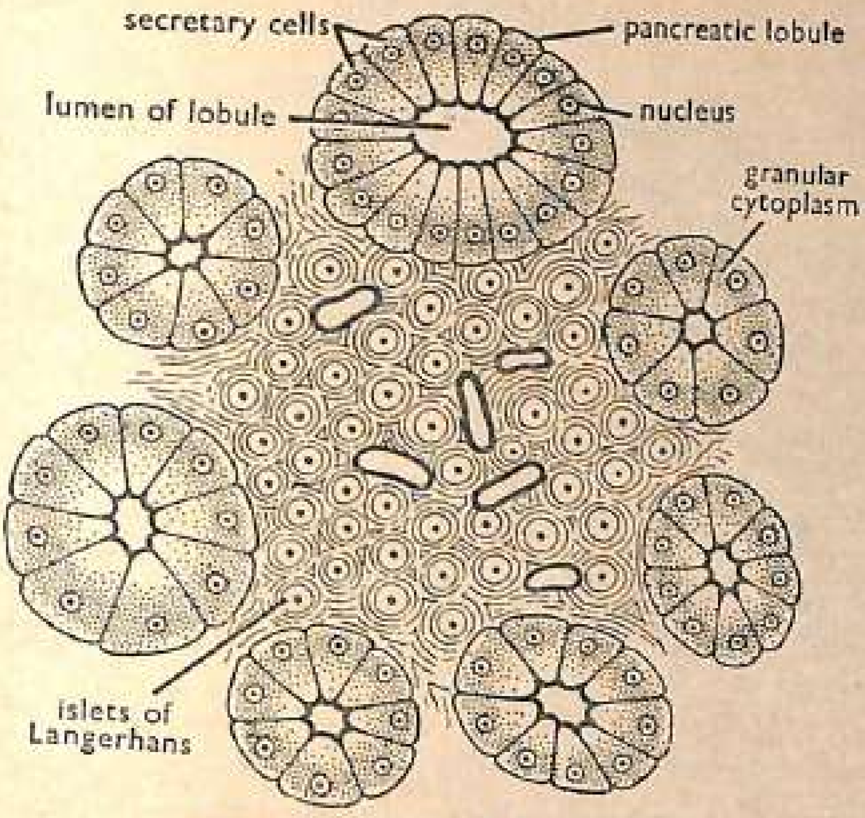


Fig. 4-42. Frog. T. S. of pancreas.

(7) **Pancreas** section is peculiar and can be easily identified by the presence of special cells, called as **islets of Langerhans**.

(8) In eosin–haematoxylin stained sections **islets of Langerhans** cells appear as rounded masses of cells with unstained cytoplasm. There are 3 kinds of cells—

(a) **α-cells** which secrete a hormone, called **glucogon**.

(b) **β-cells** secrete **insulin**. (c) Some indifferent agranular cells of unknown function.

(9) Islets of Langerhans do not have ducts and function as endocrine glands.

(10) Pancreas is very vascular and also innervated by parasympathetic nerves.

(11) Pancreas plays a dual role in the body, serving both as **exocrine** and **endocrine** glands. **Exocrine** secretion consists of digestive enzymes, such as **amylopsin, trypsin** and **lipase**. Endocrine secretion is that of islets of Langerhans which produce **insulin** and glucogon, secreted by β-cells and α-cells, respectively.

(12) **Insulin** plays an important role in carbohydrate metabolism. It regulates **blood sugar** level. Its deficiency causes a disease, called as **diabetes**. **Glucogon** increases the blood sugar level. Its deficiency causes **hypoglycemia**.

[41] FROG—T. S. of the Spleen

Comments :

(1) Spleen is a small, rounded and dark brown structure, found above rectum.

(2) The **spleen** is covered with a fibrous and muscular **capsule**.

(3) The capsule is externally covered by **visceral peritoneum**.

(4) The capsule sends bands or **trabeculae**, which ramify into the substance of the gland.

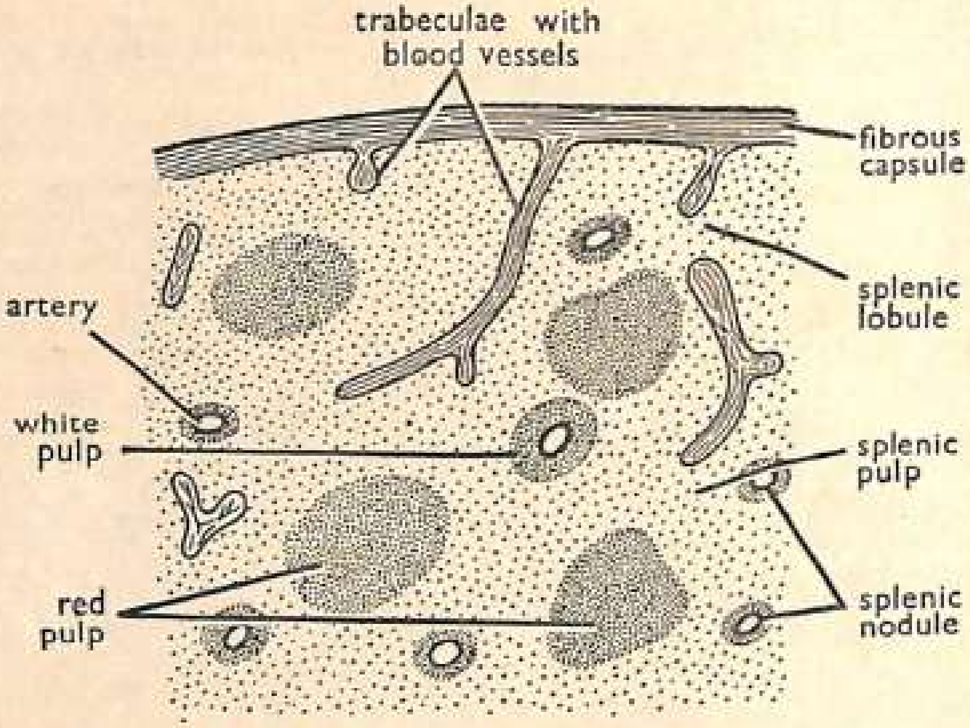


Fig. 4-43. Frog. T. S. of spleen.

(5) Into the network of the trabeculae there is a **soft pulpy** mass, called as **splenic pulp.**

(6) Splenic pulp may be **red pulp** or **white pulp.**

(7) Pulp contains 3 kinds of cells—(a) **phagocytic histocytes,** (b) reticulum cells forming network, and (c) **giant** cells with multiple nuclei.

(8) The section contains, besides the above cells, **blood** corpuscles, **malpighian** corpuscles, blood capillaries and nerves.

(9) The reticular cells and phagocytes belong to **endothelial** system.

(10) **Spleen** has the following **functions** :

(a) It produces antibodies.

(b) Spleen stores and synthesizes leucocytes (W.B.C.). Spleen is dilatable and contractile.

(c) It contains macrophages, which are responsible for the destruction of old erythrocytes.

(d) In embryonic condition it produces erythrocytes but after birth leucocytes are produced.

[42] FROG—T. S. of the Lung

Comments :

(1) There is a pair of sac-like lungs, one on either side of heart. Lung of frog is not much elongated, but it is well developed having more alveolar spaces and rich blood supply.

(2) Lungs are formed by the ramification of the **bronchi** and their terminal expansions. T. S. of lung shows the following histological details.

(3) The section comprises of lung wall, alveoli and a central cavity.

(4) The **lung wall** is composed of outer **peritoneum** made up of squamous epithelial cells, connective tissue and unstriped muscle fibers. **Inner wall** is composed of ciliated epithelial cells, **mucous** glands and **blood** capillaries.

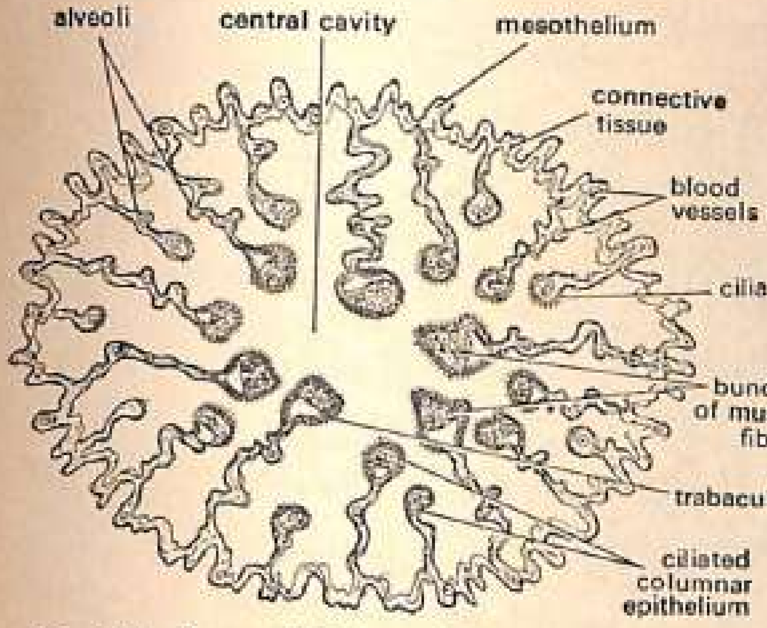


Fig. 4-44. Frog. T.S. through lung (low magnification).

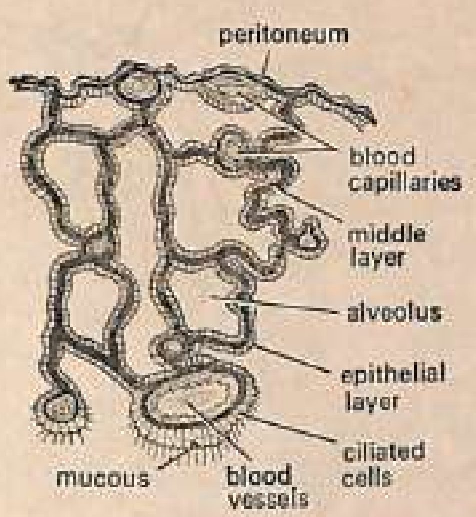


Fig. 4-45. Frog. T.S of a portion of lung highly magnified.

(5) Blood capillaries form network.

(6) The central cavity is partly divided into numerous chambers or **alveoli**, partitioned by **trabeculae**.

(7) The **trabeculae** partly contain flattened **squamous epithelium** and partly ciliated columnar epithelial cells. They are richly vascularized and muscularized.

(8) The **alveoli** and **trabeculae** increase the respiratory surface.

(9) Lung develops in the same manner as secretory gland.

(10) Lung is an important respiratory organ meant for **external respiration**, where oxygen from the atmosphere is taken to combine with haemoglobin forming **oxy-haemoglobin.** From the lungs oxy-haemoglobin is transported to cells for **tissue** or **cellular** respiration.

[43] FROG—T. S. of the Spinal Cord

Comments :

(1) Medulla oblongata, after emerging from foramen magnum, continues posteriorly as **spinal cord.**

(2) T. S. of spinal cord shows that it is coated by **piamater** and **duramater.**

(3) The **bioplasm** of the nerve cord is divided by dorsal and ventral tissues and is differentiated into outer **white matter** and inner **grey matter.**

(4) **White matter** is devoid of nerve cells.

(5) The **grey matter** contains nerve cells and a central canal, which is continued with the ventricles of brain. It is lined by a single epithelial layer, called as ependyma.

(6) **Grey matter** forms squarish area, but **dorsal** and ventral **horns** are not very much distinct.

(7) In mid-dorsal axis, dorsal and ventral tissues are seen.

(8) Spinal cord has the following functions—

(a) It receives **stimulus** from dorsal and ventral roots.

(b) It transmits impulses to the brain and from the brain. (c) It causes **reflex action.**

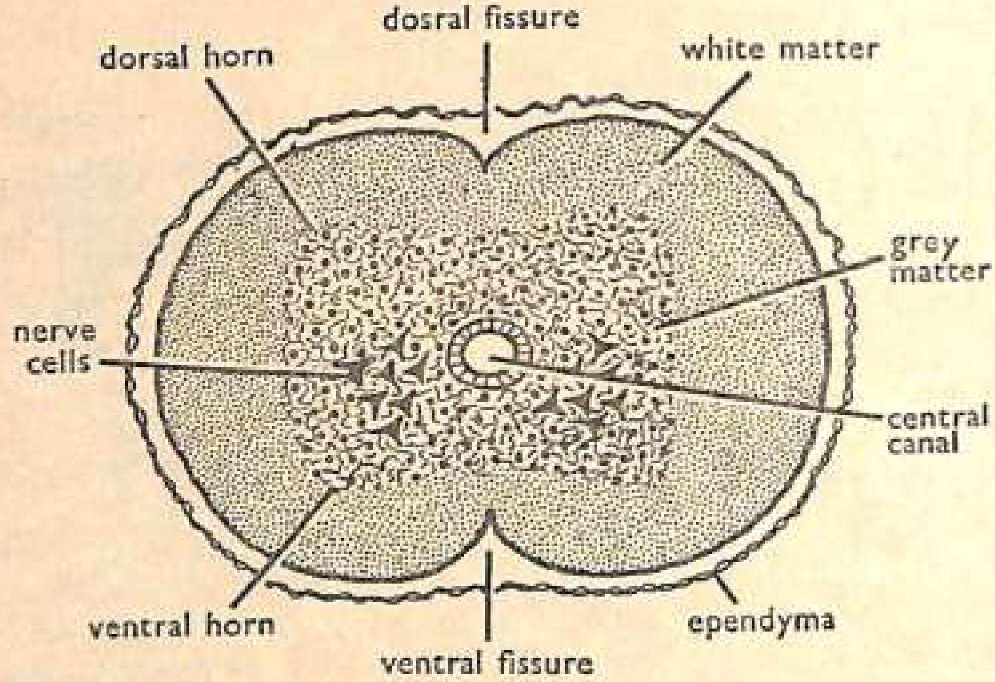


Fig. 4·46. Frog. T. S. of spinal cord.

[44] FROG—T. S. of the Kidney

Comments :

(1) The kidney of adult frog is **opisthonephros**.

(2) There are two kidneys, each representing a compound tubular gland. T. S. through a kidney shows **nephrostomes, uriniferous** tubules and **Bowman's** capsules.

(3) Each kidney is covered by visceral peritoneal layer on inner side only.

(4) **Nephrostomes**—These are funnel-like structures communicating with the coelom and to the vein of kidney. They collect excretory matter from coelom.

(5) Uriniferous tubules are cut in various planes and are lined with ciliated and glandular epithelial cells.

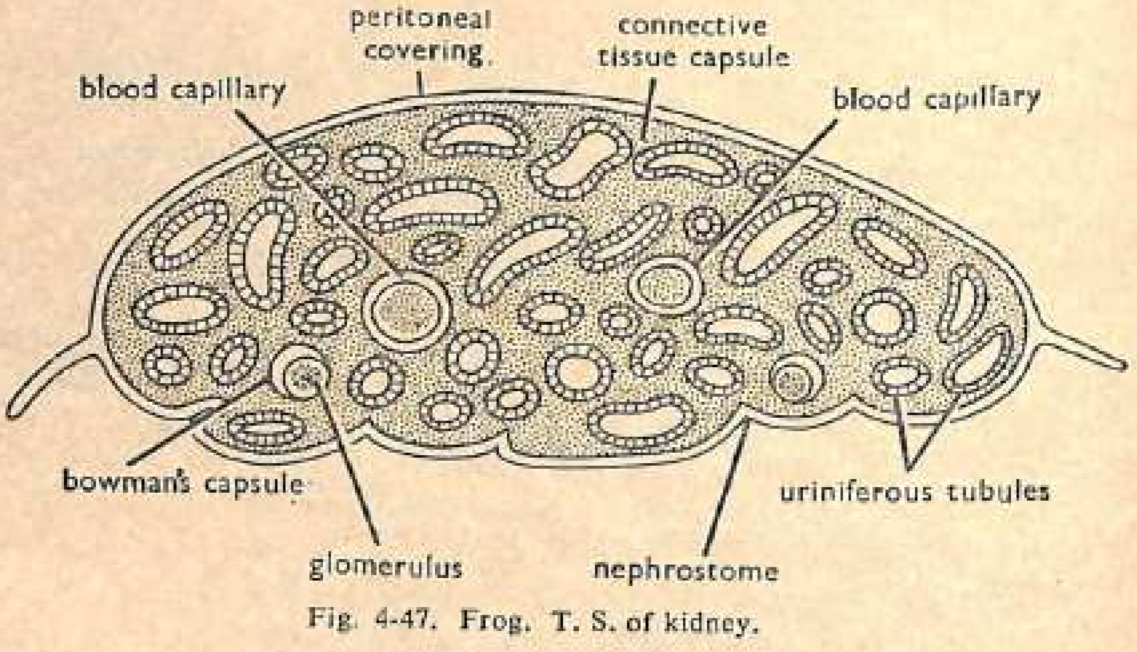


Fig. 4·47. Frog. T. S. of kidney.

(6) **Bowman's capsules** are cup-shaped structures, containing network of **afferent** and **efferent** vessels, which form **glomerulus**.
(7) Bowman's capsule and glomerulus are chief excretory filters and are collectively called as Malpighian body.
(8) **Renal** arteries and veins are cut at several places in section.
(9) Bowman's capsule leads into a uriniferous tubule, which after contributions opens into a collecting tubule.
(10) **Function of kidney**—It functions to stabilize blood stream by extracting water, urea, uric acid, phosphates and sulphates, etc. Various diseases associated with kidney are glycosuria, albuminuria and nephritis, etc.

[45] FROG—T. S. of the Testis

Comments :

(1) Testes are attached with kidney by **mesorchium** and are also associated with fat bodies.
(2) T. S. through testis shows that it is composed of **peritoneum, seminiferous tubules, interstitial cells** and **blood vessels.**
(3) Each **seminiferous** tubule is lined with germinal epithelium, the cells of which undergo spermatogenesis to give sperms.
(4) In mature testes, bundles of spermatozoa are seen in the cavity of seminiferous tubules.
(5) The **spermatogonia, spermatocytes, spermatids** and sperms representing various stages of spermatogenesis are seen in the section.
(6) The section shows cut blood vessels and connective tissue.
(7) The **interstitial** cells present in the section secrete male hormone, **testosterone,** which is responsible for developing secondary sexual characters.
(8) Sertoli cells are absent.

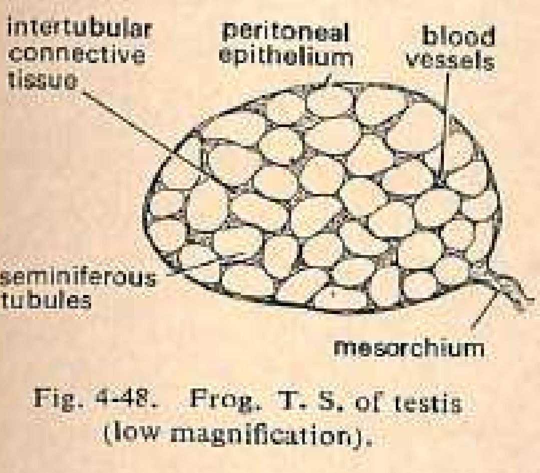


Fig. 4-48. Frog. T. S. of testis (low magnification).

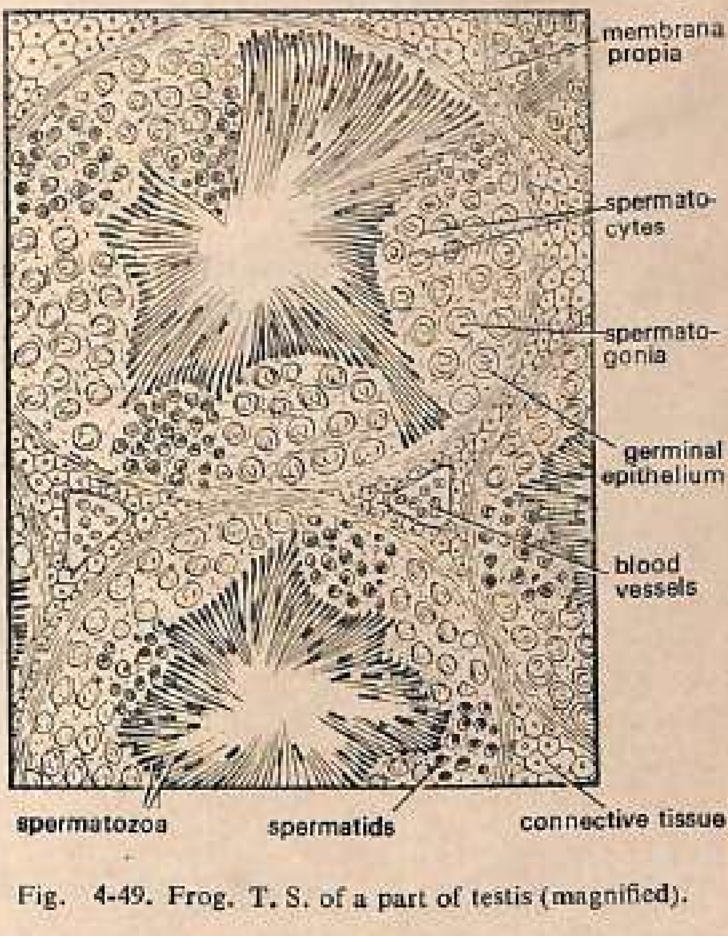


Fig. 4-49. Frog. T. S. of a part of testis (magnified).

[46] FROG—T. S. of the Ovary

Comments :

(1) There are two ovaries attached to kidneys by **mesovarium.**

(2) Each ovary is composed of several hollow **lobules** containing developing ova.

(3) Each lobule is surrounded by external **theca externa**, which corresponds to the peritoneal epithelium of the testis.

(4) It is composed of **peritoneum**, outer connective tissue layer and germinal epithelial layer.

(5) Several **sacs** of various sizes are connected to theca externa.

(6) Each sac is further covered by **theca interna**, which is made up of muscle fibres, blood vessels and nerves.

(7) The theca **interna** is incomplete at the place, where sac is connected to the outer wall of the ovary. It is at this place that ovum, when fully mature, bursts and falls out into the coelom.

(8) The **ovum** is surrounded by **follicular** cells which develop from oogonia.

(9) The follicular cells, theca externa and theca interna form **ovarium stroma** which secretes female **hormones**.

(10) Each ovum contains a nucleus for fertilization and granular yolk for nourishment.

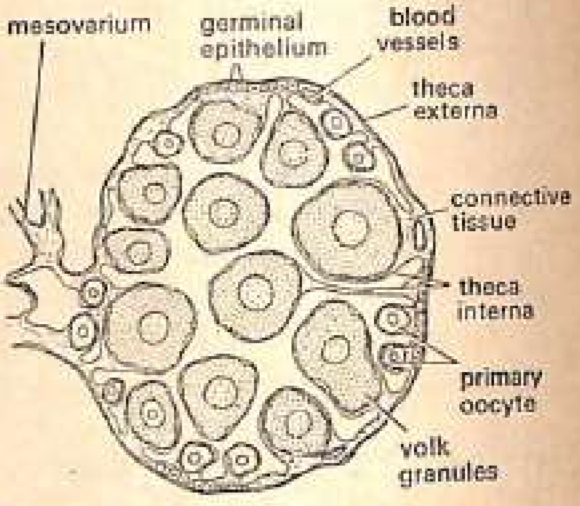


Fig. 4-50. Frog. T. S. of complete ovary.

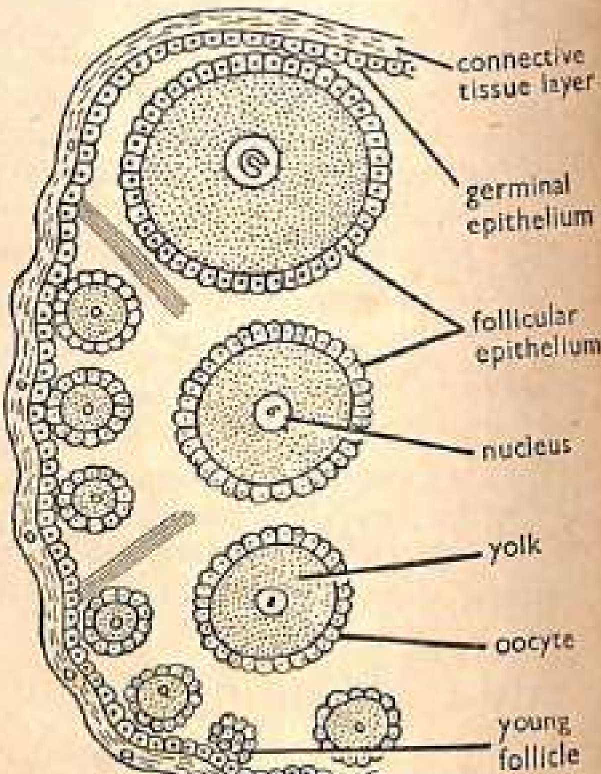


Fig. 4-51. Frog. T. S. of a part of ovary.

(11) The **ovum** is released in the primary oocyte stage. The second maturation division occurs in the water.

Identification—*By developing ova.*

E. MAMMALIA

[47] RABBIT—T. S. of the Skin

Comments :

(1) Mammalian skin is characterized by having various **glands** and **hairs** in abundance.

(2) T. S. through skin shows that it is composed of **epidermis** on outside and dermis towards inner side.

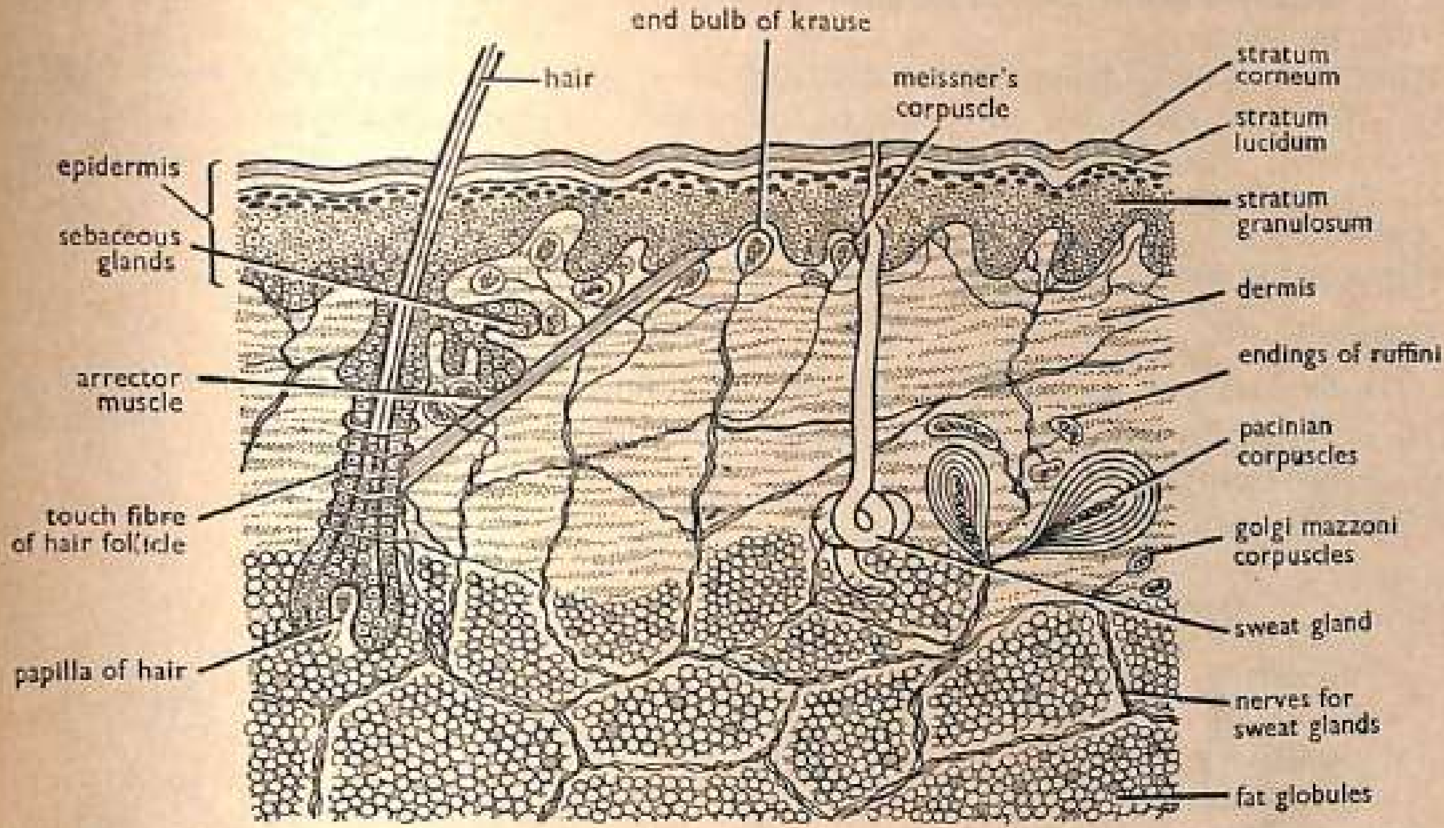


Fig. 4-52. Rabbit. V. S. of skin.

(3) **Epidermis** consists of stratified squamous epithelium, the cells of which are arranged in **strata**. The cells are arranged in four layers namely :

(a) **Stratum corneum**—Outermost cells without nucleus. It is cornified layer containing keratin.

(b) **Stratum lucidum**—Next layer consists of flat cells without granules and having **eleidin**.

(c) **Stratum granulosum**—This third layer contains granules of **keratohyalin.**

(d) **Stratum malpighii**—This is innermost layer, consisting of germinal layer. New cells are budded off from this layer mitotically and move upwards.

(4) Hairs are characteristic of mammalian skin only. Each hair is elongated structure, consisting of **hair shaft, hair follicle, hair** cuticle, hair cortex, **hair medulla, hair bulb** and **hair papilla.**

(5) **Hair shaft** projects obliquely on the body surface. **Erector muscles** move the hair involuntarily.

(6) **Dermis**—Beneath epidermis is dermis. It is formed of areolar connective tissue. It originates from dermatome and contains **collagen** fibers, **elastic** fibers, **histocytes, fibrocytes** and mast cells.

(7) **Glands**—Dermis contains various glands such as—

(a) **Sebaceous glands**—producing waterproof, oily substance.

(b) **Sweat glands**—sodoriferous.

(c) **Mammary glands**—producing milk.

(d) **Meibomian gland**—producing oily secretion in eyes.

(8) Below dermis is a subcutaneous reticular layer, consisting of panniculus **adipose globules.**

(9) **Golgi mazzoni** corpuscles, **Pacinian** corpuscles and endings of ruffini are also seen in the section.

(10) **Functions**—(a) Protective, (b) defensive, (c) maintains shape, (d) receives stimuli, (e) acts as insulators, (f) prevents loss of water due to adipose tissue, (g) excretory (sweat gland eliminates water and other waste products), (h) milk producing (by mammary glands).

[48] RABBIT—T.S. of the Stomach

Comments :

(1) Stomach is an important, sac-like structure, functioning digestive and masticatory. The cardiac T.S. is composed of **serosa**, **musculature**, **muscularis mucosa**, **sub-mucosa** and **gastric glands**.

(2) The serous coat or serosa forms outermost layer. It is derived from visceral **peritoneum** and is composed of flat squamous cells, called as **mesothelium**.

(3) **Musculature** or **muscular coat** consists of outer longitudinal fibres, middle circular fibres and inner longitudinal and oblique fibres.

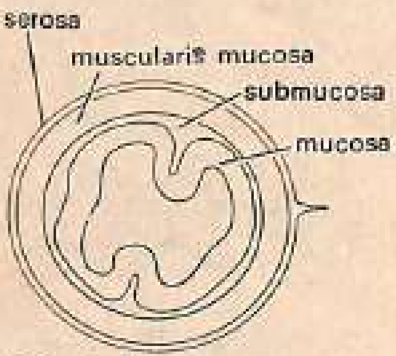


Fig. 4-53. Rabbit. T. S. of stomach (low magnification).

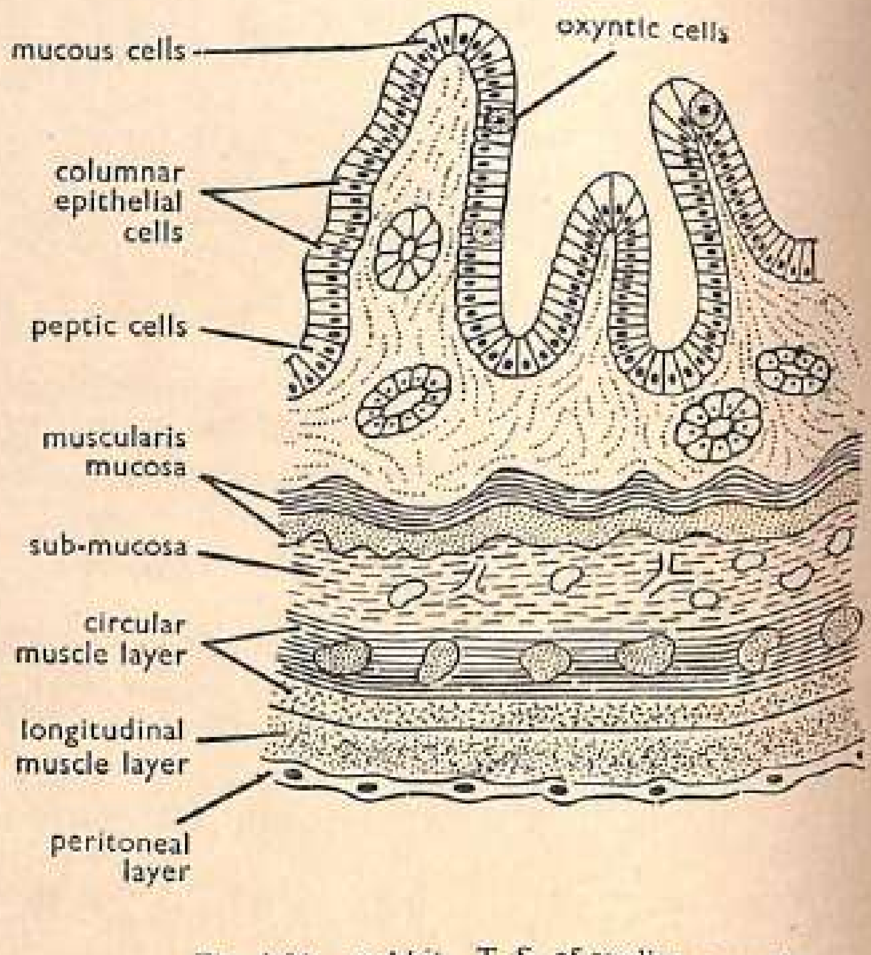


Fig. 4-54. Rabbit. T. S. of cardiac stomach. (high magnification).

(4) The **longitudinal muscles** run longitudinally and are made up of unstriped fibres. By their contraction, the stomach becomes shortened and the volume of its lumen is widened.

(5) The **circular muscles** consist of circular fibers which form thicker layer than L.M.F. By the contraction of these muscles the stomach increases in size but its lumen is reduced.

(6) The longitudinal and circular muscles become thicker towards pylorus. The **oblique** fibers are best developed in **cardiac** stomach.

(7) There is a ganglionated nerve plexus between longitudinal and circular muscles.

(8) **Muscularis mucosa** is weaker than in frog and it consists of inner circular and outer longitudinal fibers.

(9) **The submucous coat** is a layer of areolar tissue, serving to unite the mucous membrane loosely to the muscular coat, in which ramify the larger branches of the blood vessels and lymphatics.

(10) Mucosa is thrown into folds. Its inner surface is covered by **columnar** epithelial cells resting on basement membrane and **lamina propia**. Each fold contains gastric glands, which consist of mucus-secreting cells, **zymogen** or **pepsin**-secreting cells and oxyntic cells or HCl producing cells.

(11) Stomach produces **gastrin**, a hormone, which activates gastric glands to secrete digestive enzymes.

(12) **Functions**—By alternate contraction and relaxation of stomach muscles food is masticated and pushed forwards and digested. Pepsin breaks peptide bonds and converts proteins into derived proteins i.e. peptones and proteoses. Lipase hydrolyses fats into glycerol and fatty acids.

[49] RABBIT—T.S. of the Duodenum

Comments :

(1) **Duodenum** is the first part of intestine and it receives all digestive enzymes.

(2) The **T.S.** shows that it is composed of outer serosa, muscular coat, **sub-mucosa**, muscularis mucosa and **mucosa**.

(3) **Serosa** forms outer covering. It is derived from visceral peritoneum and is made up of flat **squamous** epithelial cells.

(4) **Muscular coat** consists of outer longitudinal and inner circular fibers.

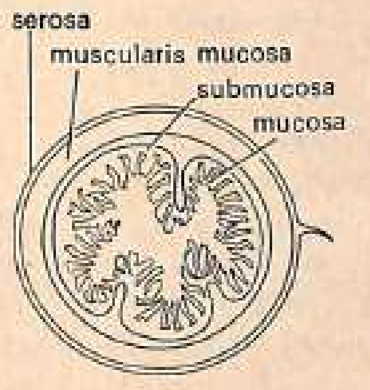


Fig. 4-55. Rabbit. T. S. of duodenum (low magnification).

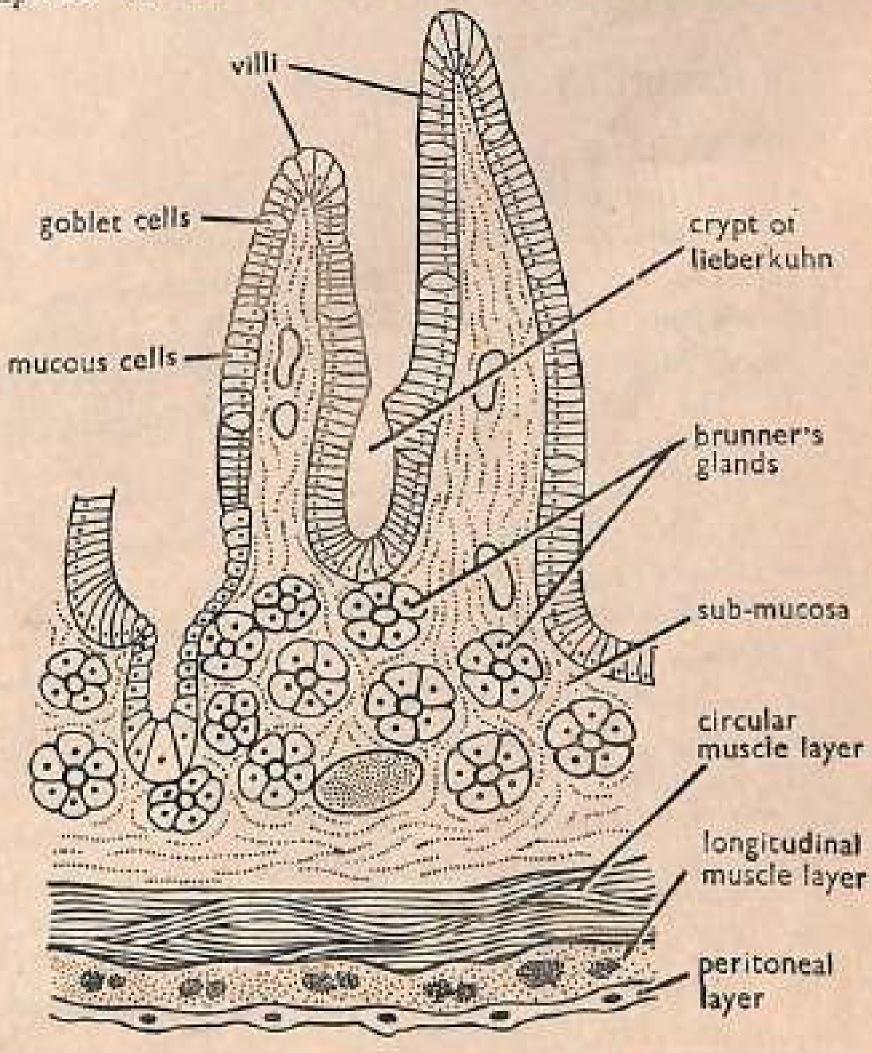


Fig. 4-56. Rabbit. T. S. of duodenum (magnified).

(5) The **longitudinal** muscles contain unstriped fibers. By their contraction duodenal tube is shortened but its volume is widened.

(6) The **circular** muscles contain thick circular fibers, which on contraction increase the size of duodenum but decrease its lumen.

(7) Between longitudinal and circular muscles lies a network of lymphatic vessels and close ganglionated plexus of amylinated nerve fibers called as **plexus myentericus.**

(8) **Sub-mucosa** is well developed and is composed of loose connective tissue. In it the blood vessels and lacteals ramify before entering or after leaving the mucous membrane. It also contains ganglionated plexus, called as plexus of **Meissner**. Its branches supply to muscles and villi.

(9) Muscularis mucosa is very much reduced.

(10) Mucosa is thrown into villi or folds composed of single-layered epithelial cells. The epithelial cells contain crypts of Lieberkuhn, which produce **succus entericus** and Brunner's glands which secrete mucus.

(11) Duodenum receives three kinds of digestive enzymes—(a) pancreatic juice containing trypsin, amylase and lipase, (b) bile juice containing bicarbonate, glycocholate and taurocholate, and (c) succus entericus containing peptidase, lipase, invertase, maltase and lactase. These enzymes are secreted in response to two hormones secreted in duodenum : (i) **cholechystokinin** which stimulates liver to secrete bile juice, and (ii) **secretin** which stimulates pancreas to secrete pancreatic juice. In duodenum food is converted into amino acids, polypeptides, maltose, glycerols and fatty acids.

[50] RABBIT—T. S. of the Liver

Comments :

(1) Liver of rabbit is a five-lobed structure. T. S. passing through liver shows **hepatic lobules**, bile ducts, blood vessels and connective tissue.

(2) The liver is a solid **glandulo-reticular organ** made of **polyhedral** cell masses or **heptic lobules** measuring 1 mm. in diameter. Externally liver is covered with serous coat.

(3) Liver has several functions as storage of glycogen, excretory and oxidation of sugar.

(4) The **bile canaliculi** lie among the hepatic cells and connect in groups forming **bile** ductule.

(5) Each hepatic lobule is pierced everywhere with a network of **sinusoid blood vessels** called as **hepatic capillaries** from introlobular hepatic arteries and intralobular hepatic vein.

(6) Conspicuous cells occur at intervals on the walls of the sinuses. These are called as **stellate** or **Kupffer** cells. They are highly phagocytic and they ingest erythrocytes and other suspended particles.

(7) Liver cells contain fats and glycogen.

(8) **Functions**—(i) Liver is a very important organ for metabolism.

(ii) It secretes bile juice consisting of bile salts, bile pigments and lecithin.

(iii) It stores glycogen, inorganic salts of iron and copper.

(iv) Glycogenesis and Glycogenolysis take place in liver.

(v) Liver produces fibrinogen and prothrombin which are essential components of blood clotting. It also produces **heparin**, an anticoagulant substance.

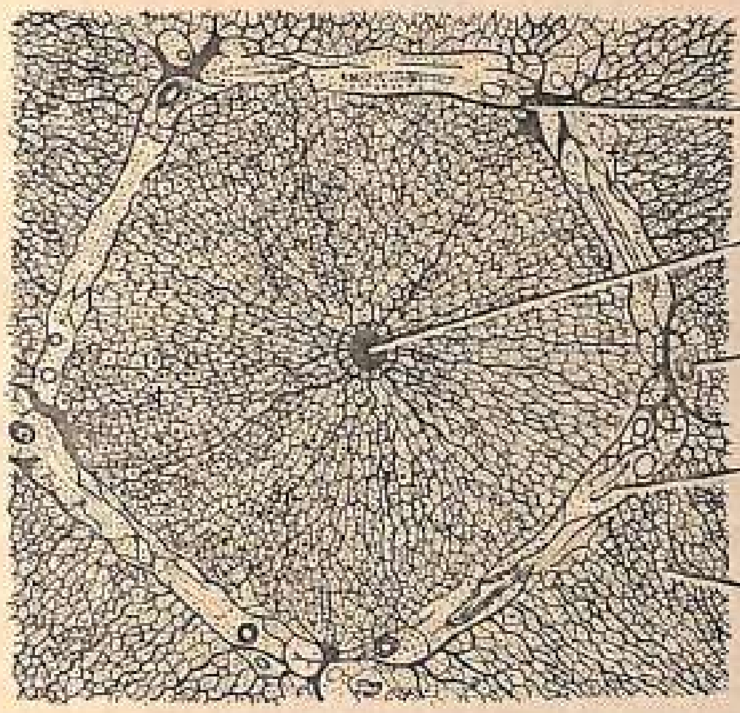


Fig. 4-57. Rabbit. T. S. of the liver.

(vi) Liver changes ammonia into urea by **ornithine** cycle.
(vii) It controls oxidation of sugar. (viii) Various enzymes are synthesized in liver.
(ix) It also stores and synthesizes vitamins.
(x) In embryonic condition it produces blood corpuscles.

[51] RABBIT—T. S. of the Pancreas

Comments :

(1) Pancreas is a very important digestive gland. T.S. passing through it shows that it is composed of various **alveoli** or **acini**. It is a compound tubulo-alveolar **racemose** gland consisting of both exocrine and endocrine parts.
(2) The mammalian pancreas can be distinguished from frog in having distinct lobulations, stroma, connective tissue and **islets of Langerhans**.
(3) The pancreatic lobes, covered by coelomic epithelium, represent **exocrine** part.
(4) Each lobule contains bunch of **secretory cells** and a central lumen connected by loose connective tissue.
(5) The cytoplasm of each lobule is filled with granules and in a haematoxylin-stained section, outer part is deeply coloured due to concentration of **mitochondria**.
(6) The granules are regarded as precursor of pancreatic secretion which are **amylopsin, tripsinogen** and **lipase**.
(7) **Amylopsin (amylase)** acts on starch and glycogen and changes them into maltase. Trypsinogen (**trypsin**) acts on peptones and proteoses to change them into amino acids and **lipase** hydrolyses fats into fatty acids and glycerols.
(8) The **endocrine islets** of **Langerhans**, in eosin-haematoxylin-stained sections, appear as rounded mass of cells with unstained cytoplasm and they contain 3 kinds of cells.
   (a) Alpha cells (α-cells) which secrete a hormone called as **glucogon**. It increases **blood sugar** level in the body and its deficiency causes **hypoglycemia.**

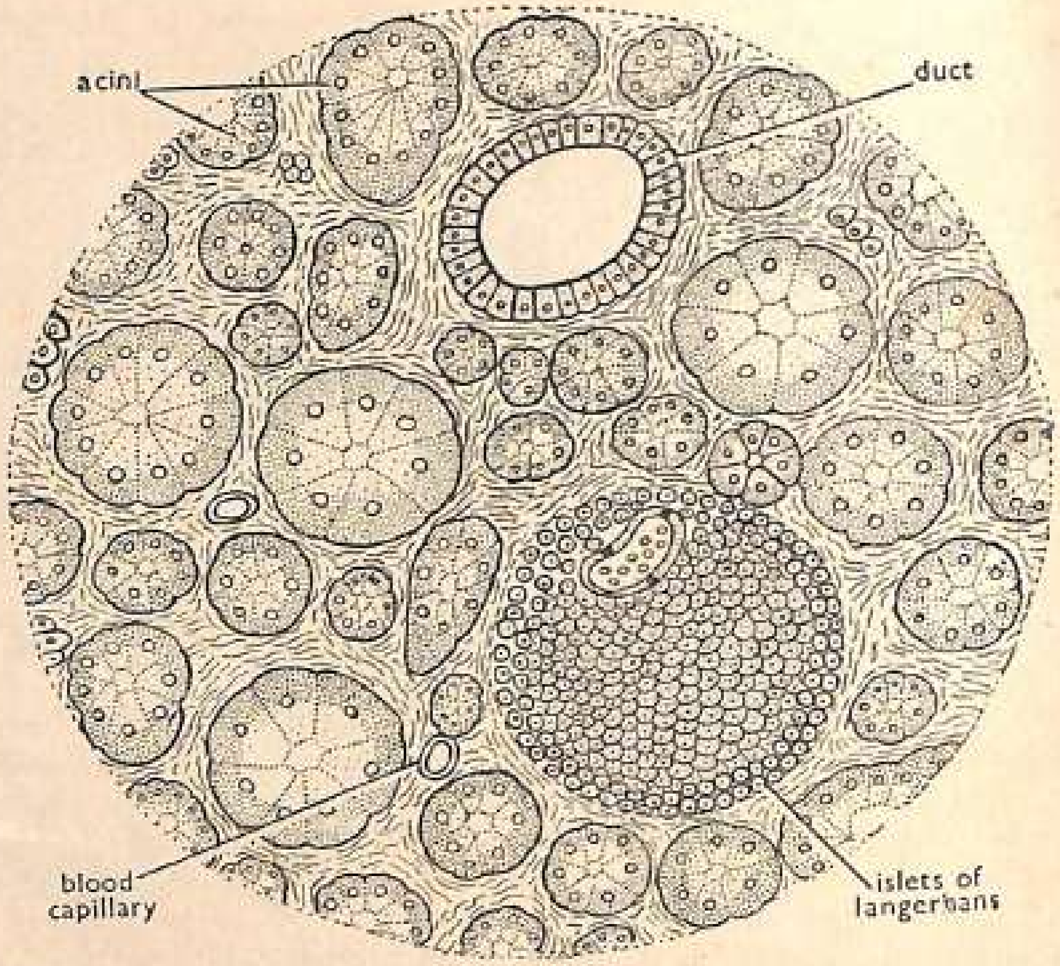


Fig. 4-58. Rabbit. T. S. of the pancreas.

(b) Beta cells (β-cells) secrete another hormone, **insulin**, which plays an important role in carbohydrate metabolism. Its deficiency causes **diabetes**. It regulates blood sugar level.

(c) Some unknown undifferentiated cells.

(9) Pancreas is richly vascularised.

(10) It is also innervated by various nerves with several small parasympathetic ganglia.

[52] RABBIT—T. S. of the Spleen

Comments :

(1) Spleen is the largest lymphoid endocrine gland.

(2) It is dark brown in colour and composed of muscular and fibrous coat, trabeculae, red pulp, white pulp and richly vascularised.

(3) The spleenic coat or capsule is externally covered by visceral peritoneum.

(4) **The capsule** sends **bands** or **trabeculae**, which form a network in the substance of the gland.

(5) In the interstices of the framework lies a soft **pulpy** substance, called as **spleen pulp** which may be red or white.

(6) The **red pulp** forming the bulk gives red colour to spleen.

(7) Pulp contains 3 kinds of cells—(a) **phagocytic histocytes**, (b) reticulum cells forming network, and (c) multinucleated giant cells.

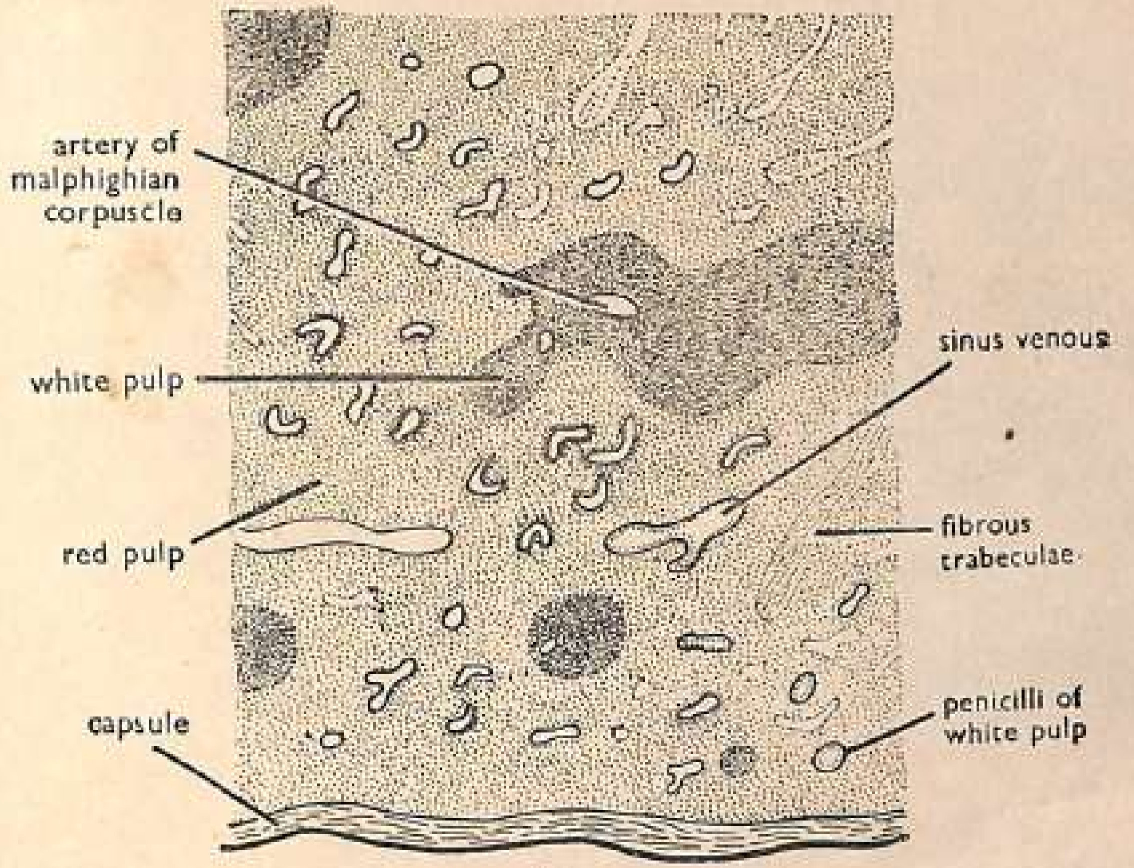


Fig. 4-59. Rabbit. T.S. of spleen.

(8) The section also contains blood corpuscles, malpighian corpuscles, blood capillaries and nerves.

(9) The reticular and phagocytic cells belong to endothelial system.

(10) Spleen has following functions—(a) It produces antibodies. (b) It stores and synthesizes leucocytes. (c) It contains macrophages which destroy old erythrocytes. (d) In embryonic condition it produces erythrocytes but after birth leucocytes are produced.

[53] RABBIT—T.S. of the Thyroid Gland

Comments :

(1) It is the most familiar endocrine gland, consisting of right and left lobes connected across to the ventral side of trachea by **isthmus.**

(2) **Thyroid** gland comprises of a framework of connective tissue, enclosing numerous rounded or oval **vesicles.**

(3) Histologically it consists of a number of rounded **thyroid follicles** of various sizes, separated by one another by connective tissue strands.

(4) Each follicle is lined with a single layer of cuboidal epithelial cells having many **mitochondria** and reticular apparatus of **Golgi.**

(5) The cavities of the vesicles are occupied by a peculiar viscous liquid, called as **thyroid colloid.**

(6) The colloid of thyroid contains organically combined iodine in the form of **thyroglobulin** having active component called as **thyroxin.**

(7) Thyroid is richly supplied with the blood vessels.

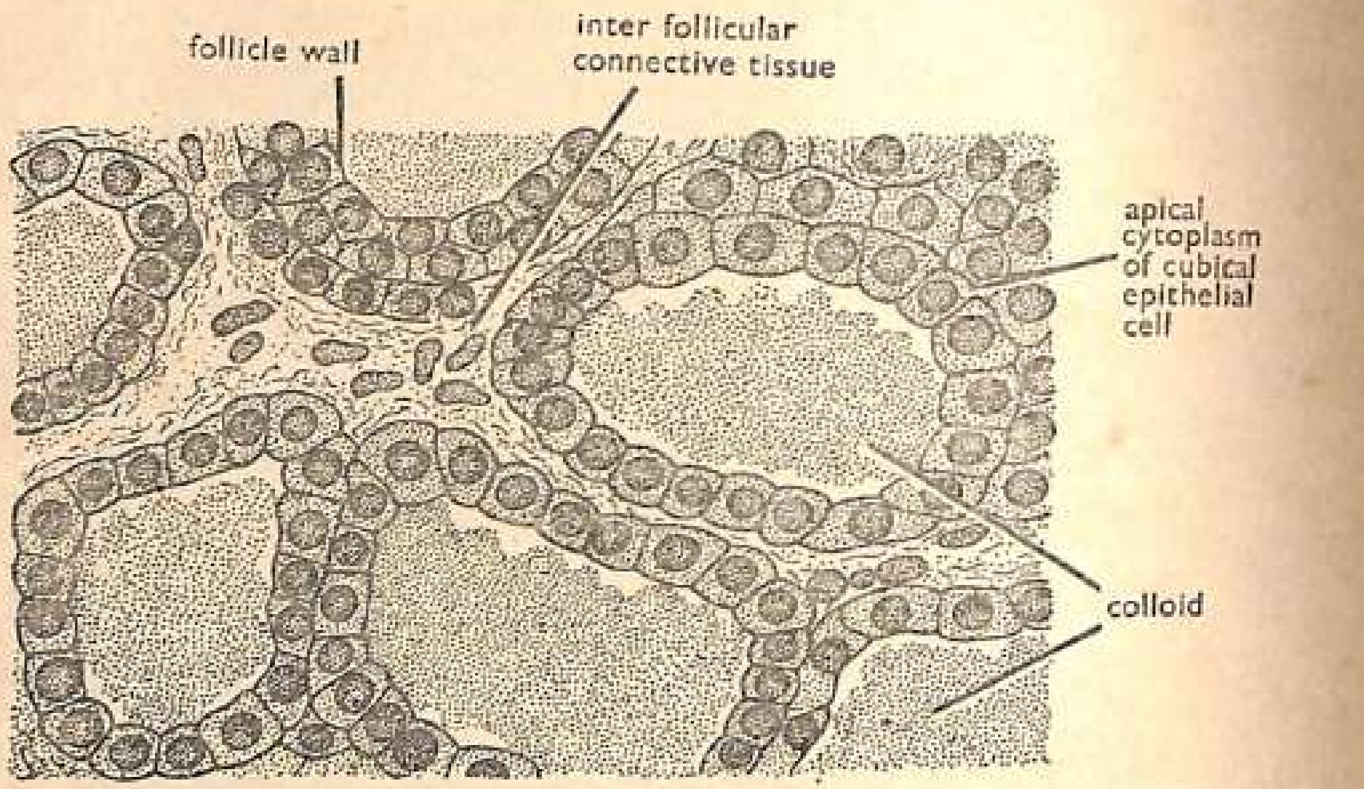


Fig. 4-60. Rabbit. T.S. of thyroid gland.

(8) **Thyroid** secretes *thyroxin* ($C_{15}H_{11}O_4N_{14}$) which contains an amino acid and 65 per cent of iodine.

(9) **Nerve fibres** of **sympathetic** origin innervate thyroid gland.

(10) **Thyroxin** controls entire metabolism. Its deficiency causes lowered metabolism. **Hyperthyroidism** results in protrusion of eye-balls. Removal of thyroid from the frog tadpole stops metamorphosis. Thyroid gland is controlled by thyroid stimulating hormone.

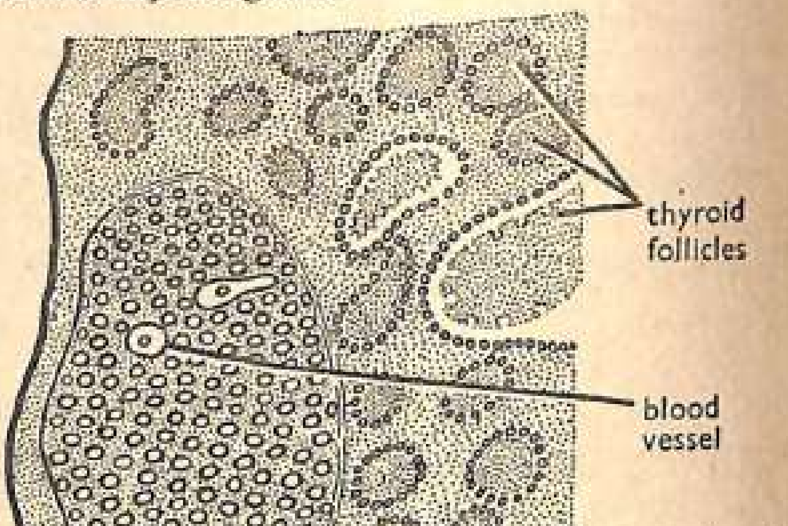


Fig. 4-61. T.S. of parathyroid gland.

[54] RABBIT—T.S. of the Parathyroid Gland

Comments :

(1) Two parathyroid glands are always found embedded in the substance of the thyroid or found on each side of the thyroid gland.

(2) Each parathyroid is enclosed within a capsule.

(3) Each parathyroid is a glandular organ consisting of columns of epithelial cells.

(4) The gland contains **chief cells, colloid** or **oxyphil cells,** separated by the connective tissue.

(5) Parathyroid produces a hormone called as parathormone, which is devoid of iodine.
(6) Removal of parathyroid causes tetany or death.
(7) Numerous sinusoid blood channels run between the columns.
(8) Its secretion controls calcium and phosphate concentrations in the blood plasma and it also controls their metabolism in the body.
(9) It also plays an important role in bone and tooth formation.
(10) Parathyroid gland develops as epithelial outgrowth from the third and fourth branchial clefts of the embryo.

[55] RABBIT—T.S. of the Adrenal Gland

Comments :

(1) Adrenal glands lie at the ends of kidneys and are two in number.
(2) T.S. passing through the adrenal gland shows that it is composed of outer vertically striated, yellow coloured **cortex** and inner soft, highly vascular and dark brown **medulla**.
(3) The entire gland is covered by **fibrous capsule**, which sends septa into the cortex and divides it into 4 zones.
(a) **Zona glomerulosa**—This zone is found below the capsule. It comprises of **columnar** cells. This zone controls the mineral and water balance of the body and also fat and carbohydrate absorption. The active **hormone** is **deoxycorticosterone** which is not under pituitary control.

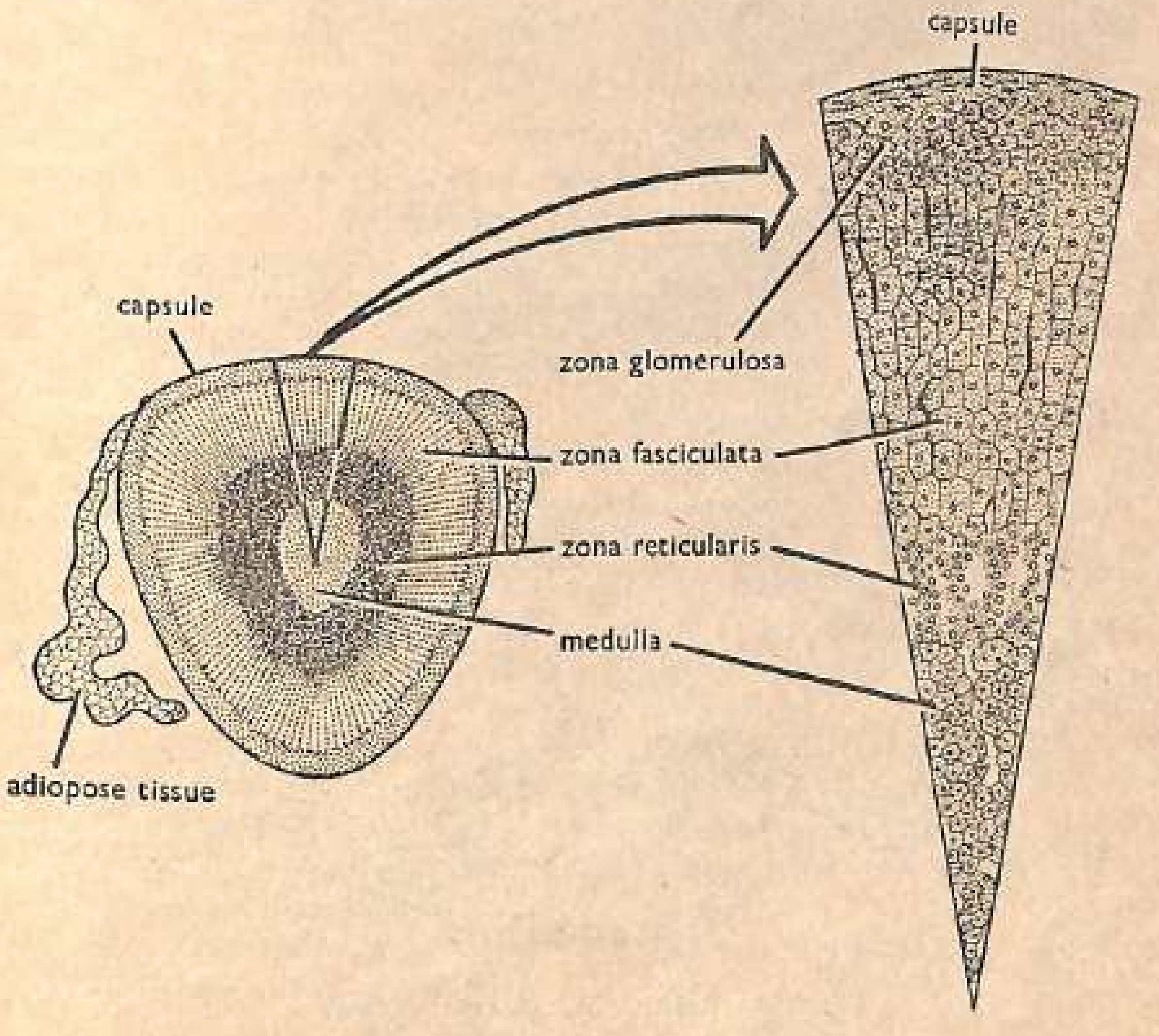


Fig. 4-62. Rabbit. T.S. of adrenal gland.

(b) **Zona fasciculata**—This zone consists of **compressed** cells which secrete **corticosterone** to control **carbohydrate metabolism.** This hormone also causes disintegration of **lymphocytes** and release of their **antibodies.**

(c) **Zona reticularis**—Next to medulla, this zone consists of pigmented reticular cells. This zone secretes sex hormones.

(d) **X-zone**—Sometimes, as in young mice, there is extra zone between zona reticularis and medulla.

(4) **Medulla** has irregularly disposed cells.

(5) It contains **elastic** fibres and **sinusoids** (large blood spaces).

(6) The medulla cells have granular cytoplasm which take dark stain with **osmic vapour.**

(7) In some medulla cells there are **chromoffin bodies** or **paraganglia**.

(8) Stimulation of the sympathetic supply to the gland causes the secretion of **adrenaline.**

(9) Medulla also secretes another hormone, **epinephrin**, which causes contraction of smooth muscles and also hastens conversion of glycogen into glucose.

(10) Cortex has mesodermal origin and medulla neuroectodermal and have abundant blood supply.

[56] RABBIT—T.S. of the Lung

Comments :

(1) The lungs are found in a pair of airtight **pleural cavities** and covered by **visceral pleura** containing blood vessels and lymphatic vessels.

(2) The lungs are formed by the ramification of the **bronchi** and by their

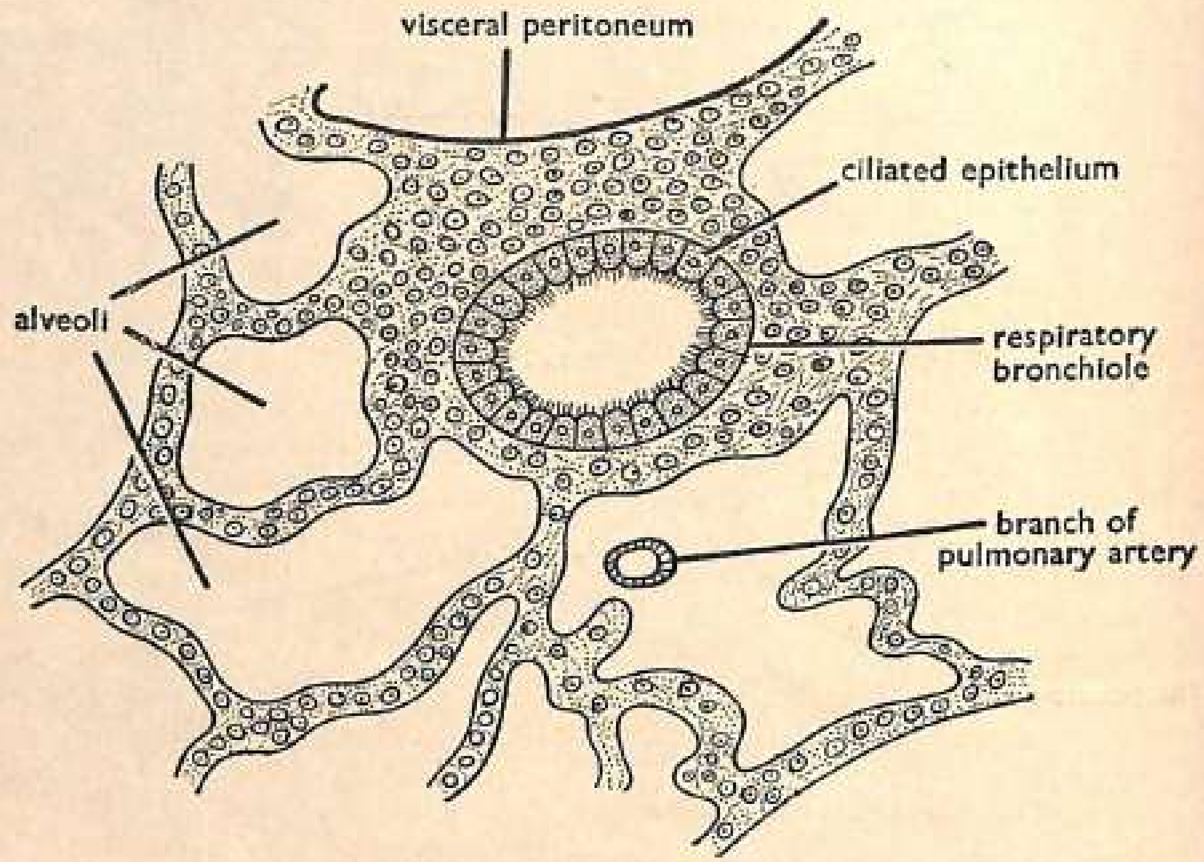


Fig. 4-63. Rabbit. T.S. of a part of lung.

terminal expansions, which form groups of lobulated or sacculated **alveolar ducts** beset with small irregularly hemispherical bulgings called as **plumonary alveoli** or **air cells.**

(3) Histologically, of in a T.S. lung, **bronchi, alveoli, blood vessels, lymphatics** and nerves are seen.

(4) The **bronchi** are lined by the **ciliated epithelium** resting on a basement membrane.

(5) External to epithelial cells is a layer of mucous membrane, containing large number of longitudinal **elastic fibers** and some **lymphoid** tissue.

(6) Outside to fibre layer is a muscle layer comprising of incomplete circular fibres.

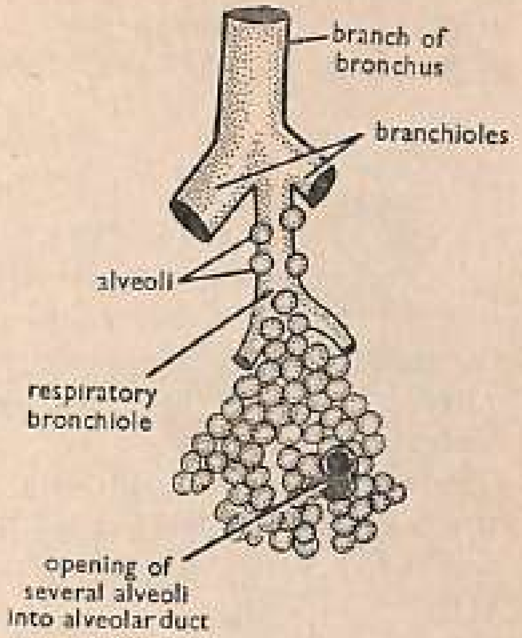


Fig. 4·64. Rabbit. T.S. of branchioles.

(7) Next to muscle layer is a loose fibrous tissue having bronchi, cartilage plates and mucous glands. The extremities of the **respiratory bronchioles** give upto 10 **alveolar ducts.**

(8) The **alveoli** have two kinds of cells—(i) groups of small cubical and thick cells, and (ii) extremely thin anucleated cells made up of thin layer. The **alveolar wall** consists of delicate connective tissue of elastic fibres having dust-containing **phagocytes or dust cells.**

(9) **Networks** of pulmonary artery and pulmonary vein are seen on the alveoli. **Lymphatics** accompany bronchi. **Nerves** from **vagus** and sympathetic innervate lung.

(10) Lung is a very important respiratory organ, where atmospheric O_2 combines with **haemoglobin** to form **oxyhaemoglobin** in blood capillaries. From the lungs oxyhaemoglobin is transported to body for cellular respiration. CO_2 is also expelled from the body through the lungs.

[57] R ABBIT—Sagittal Section of Kidney

Comments :

(1) Kidney is metanephric, compact, bean-shaped, retro-peritoneal, compound, tubular gland, attached to dorsal body wall.

(2) Sagittal section of the kidney reveals two distinct portions—(i) **cortex**, and (ii) **medulla**. Between these two zones is undefined boundary zone characterized by large blood veesels.

(3) The **medulla** is subdivided into the conical portions called as **pyramids**.

(4) The cortex and medulla are entirely composed of **uriniferous tubules**, which have straight direction in the medulla and contorted arrangement in the cortex.

(5) The groups of straight tubules pass from the medulla through the thickness of the cortex forming **medullary rays.**

(6) Between medullary rays are the deep cortical downgrowths, called as **columns of Bertini.**

(7) The uriniferous tubules begin in the cortical part of the organ in dilatations as **Bowman's capsule**, which encloses convoluted tuft of blood capillaries, called as **glomerulus.**

(8) The capsule is lined by flattened epithelium. The **glomerulus** is formed by branches of afferent and efferent vessels. The **tubule** leaves the capsule by neck and it forms **proximal convoluted, ascending** limb, descending limb and **loop of Henle.**

(9) The **renal** artery, **renal** vein, and ureter enter at the **hilum.** Branches of the ureter form major and minor calyces.

(10) Kidney is the most important excretory organ. It filters from the blood water, urea, uric acid and phosphates.

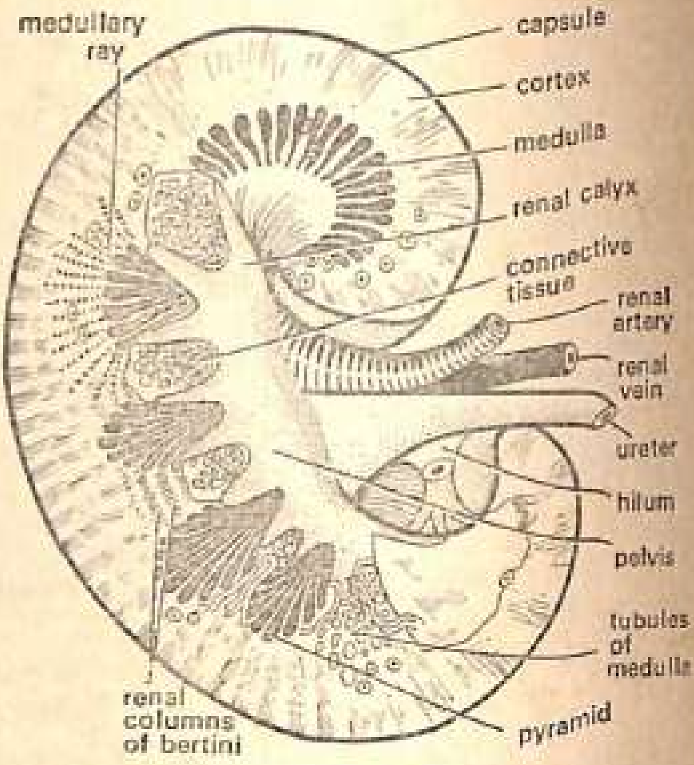


Fig. 4-65. Rabbit. L. S. of kidney.

[58] RABBIT—T. S. of the Testis

Comments :

(1) There is a pair of smooth, oval-shaped testes, enclosed in a thin but tough and fibrous envelope, called as **tunica albuginea**, which is externally covered by **serous epithelium.** Testes are found in scrotal sacs.

(2) Histologically each testis is internally divided into a number of lobules with occasional internal communications and separated by connective tissue.

(3) The glandular substance of the testicle is wholly made up of convoluted **seminiferous tubules.**

(4) The **interseminiferous tubular** tissue is formed by **connective tissue**, which holds the tubules together and contains blood vessels.

(5) Between connective tissue are rounded **interstitial cells** which produce a hormone, called as **testosterone.** The testosterone is responsible for the development of male secondary sexual characters.

(6) In the seminiferous tubules are some nutritive **cells of sertoli.**

(7) The seminiferous tubules appear rounded or oval in section. Each tubule is surrounded by a thin basement membrane lined by **germinal epithelium.**

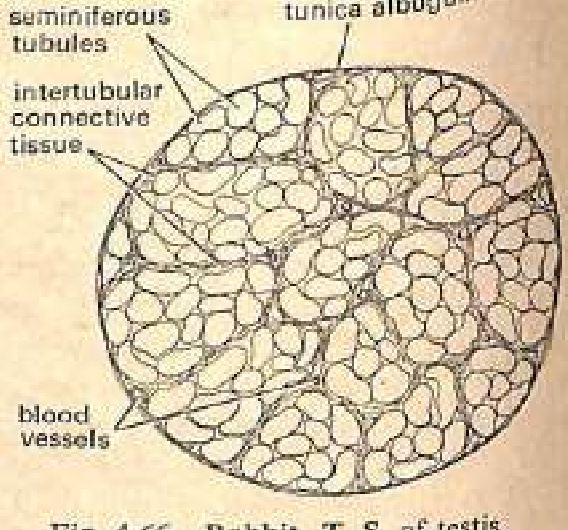


Fig. 4-66. Rabbit. T. S. of testis (low magnification).

(8) From basement membrane to inwards there are several kinds of cells :

(i) **Spermatogonia** lie along the periphery of the tubule and appear closely packed together.

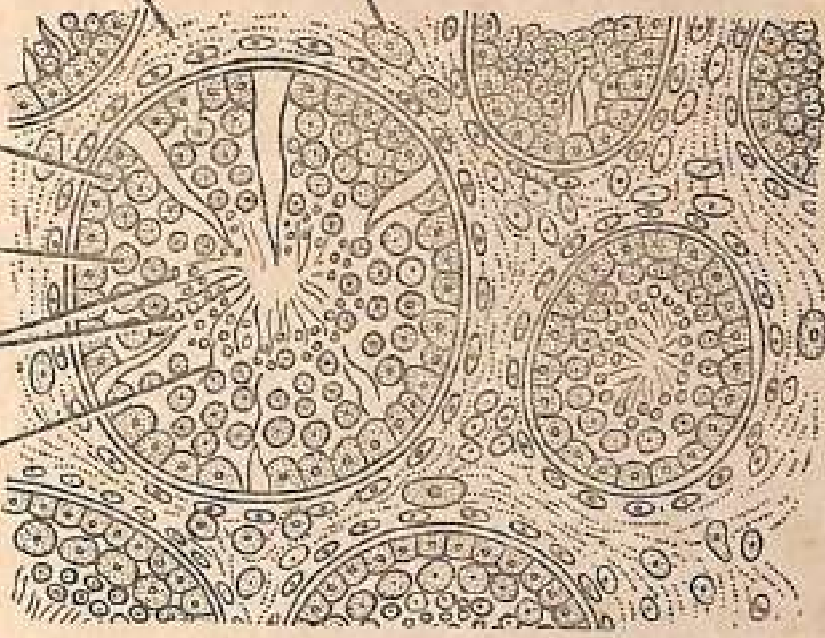


Fig. 4-67. Rabbit. T. S. of testis (magnified).

(ii) **Primary spermatocytes**—They have the largest cells and large nuclei.
(iii) **Secondary spermatocytes**—Smaller cells with deeply stained nuclei.
(iv) **Spermatids**—Small clusters of cells with condensed nuclei.
(v) **Spermatozoa** or **sperms** lie in the cavity of the tubule.

(9) **Sperm** has **head** and **tail.**
(10) The nucleus of the sperm lies in the head which is pointed at the **acrosome.**

[59] RABBIT—T. S. of the Ovary

Comments :

(1) Ovary is a solid structure lying at the back of the peritoneal cavity. It is covered by **peritoneum** consisting of **cubical cells**, forming **germinal epithelium**. The ovary is attached at the **hilus** by **mesovarium** with the **uterus**. The germinal epithelium is bounded by connective tissue, called as **tunica albuginea**.
(2) The hilus is characterised by having **helicine arteries**. Several **primary oocytes** are seen beneath germinal epithelium. Mature follicle is called as **Graffian follicle**. All the structures lie in ovarian **stroma** which is made up of connective tissue, fibroblasts, collagen, reticular fibres, nerves, blood vessels and lymphatics.
(3) **T. S.** passing through ovary or Graffian follicle shows following important structures.
(4) Each **Graffian follicle** is made up of a wall, called as **theca folliculi** consisting of **ovum** and **epithelium.**
(5) In the smallest follicle ovum is single layered; in larger ones it has 2 layers, while in still larger ones the 2 layers are formed by several **strata** of cells.
(6) The cells lining the cavity of the follicle are termed **membrana granulosa**, while the mass of cells surrounding immediately ovum are called **cumulus** or **discus prodigerous.**
(7) The fully mature **oocyte** is surrounded by the thick transparent membrane, called as **zona pellucida**, which is covered by another layer **corona radiale.**
(8) **Zona pellucida** contains yolk and fat droplets.

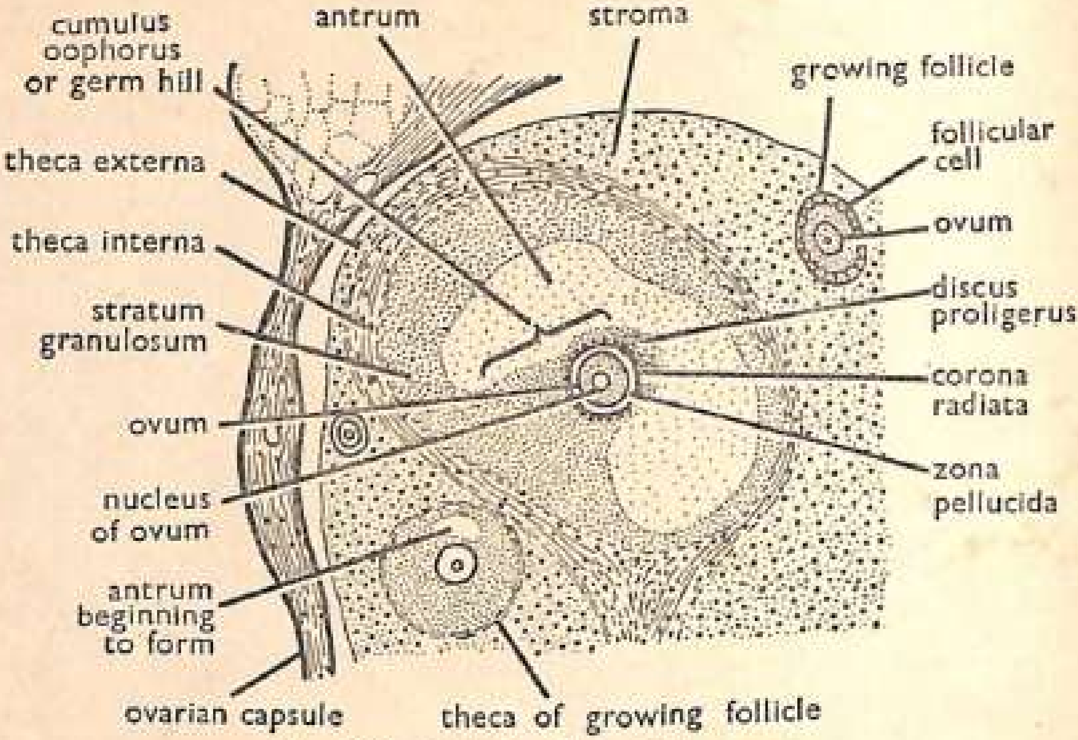


Fig. 4-68. Rabbit. T. S. of the ovary.

(9) After the extrusion of ova, a yellowish mass is left, called as **corpus luteum**, which produces a hormone **progesteron.** It facilitates the implantation of the fertilized ovum in the uterus and it also inhibits ovulation during pregnancy.

(10) Regression of **corpus luteum** leads to the formation of **corpus albicans.** The column of luteal cells shows degenerative changes with the appearance of fat globules and collagen fibres.

Chapter **5**

Study of Embryological Slides

A. DEVELOPMENT OF FROG

[1] FROG—Structure of Ovum

Comments :

(1) The ovum or egg is rounded in shape and covered by albumen layer, chorion and vitelline membrane.
(2) Vitelline membrane swells up on the exposure to water. The interspaces contain minute plants, which give oxygen by their manufacture of food to the embryo.
(3) The cytoplasm of the egg contains yolk and nucleus.
(4) Blackish brown pigment granules of melanin assemble at future animal hemisphere forming a superficial pigmented layer.

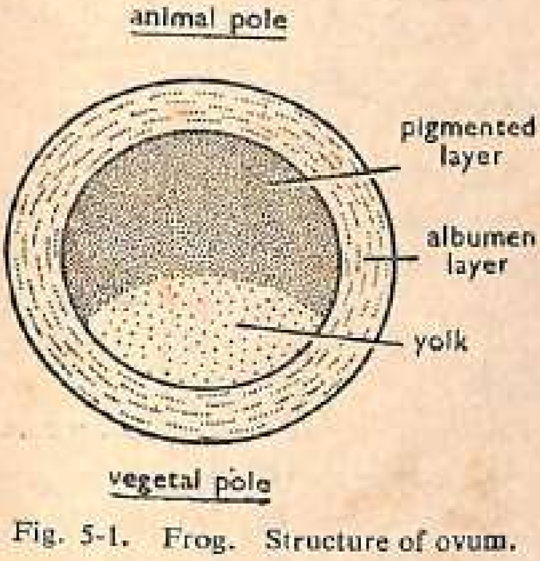


Fig. 5-1. Frog. Structure of ovum.

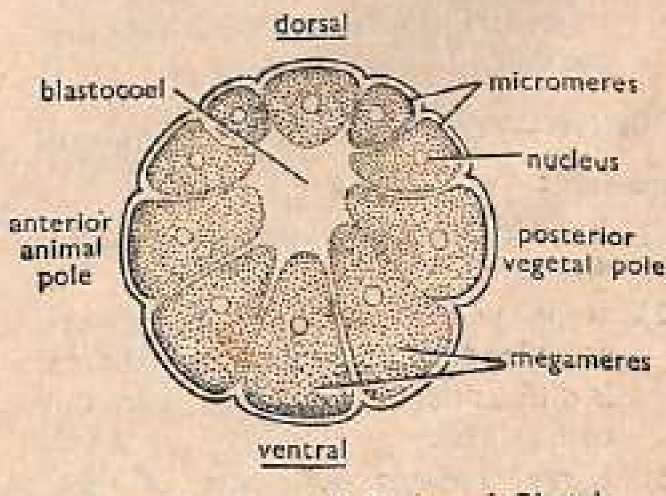


Fig. 5-2. Frog, V. S. through Blastula.

[2] FROG—V. S. through Blastula

Comments :

(1) After the cleavage of fertilized egg results the **blastula** at eight-celled stage.
(2) The blastula contains a blastocoel cavity surrounded by blastomeres.
(3) The smaller blastomeres are called as **micromeres**, found in upper half and contain dark pigments.
(4) The larger blastomeres are called as **macromeres**, found in more than lower half and laden with yolk.

[3] FROG—V. S. through Gastrula

Comments :

(1) The future prospective organ forming cells are organized at their proper places at gastrula stage.

(2) Gastrulation occurs by epiboly, blastopore involution and invagination. During this process mesodermal and notochordal cells migrate inside, forming roof of archenteron.

(3) V. S. shows that gastrula is composed of three layers—outer layer is of ectoderm cells, inner layer is of endoderm cells, forming lining of archenteron, and mesoderm separates on either side of notochord.

(4) Other structures seen in section are dorsal lip of blastopore, yolk plug, ventral lip of blastopore, chorda cells and neural plate. The blastocoel is reduced due to the development of archenteron.

(5) Gastrula has three germinal layers, namely, ectoderm, endoderm and mesoderm, from which various organs are derived.

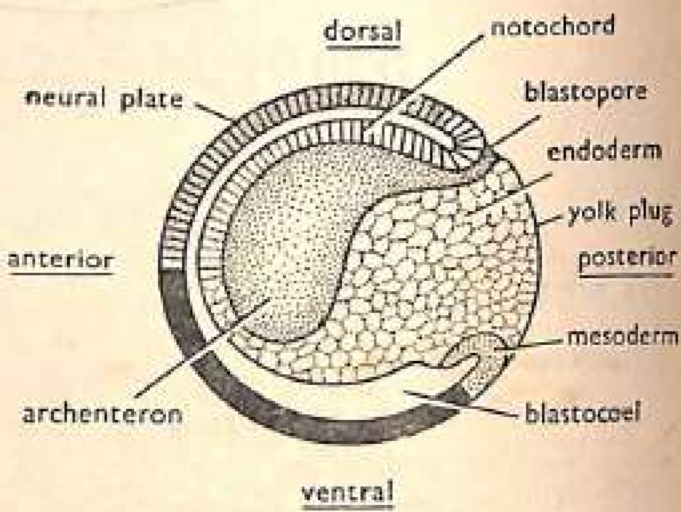


Fig. 5-3. Frog. V. S. through Gastrula.

[4] FROG—Tadpole larva whole mount

Comments :

(1) Egg hatches into tadpole larva within 48 hours.

(2) It is whitish with dark pigment granules and 5–6·5 mm. long. Larva is differentiated into body and tail with tail fin.

(3) Larva contains rudiments of eyes, olfactory pit, gill clefts, stomodaeum, cloaca and myotomes.

(4) Mouth contains horny jaws or teeth and larva feeds on vegetation. Intestine is coiled.

(5) Tadpole larva metamorphoses into adult.

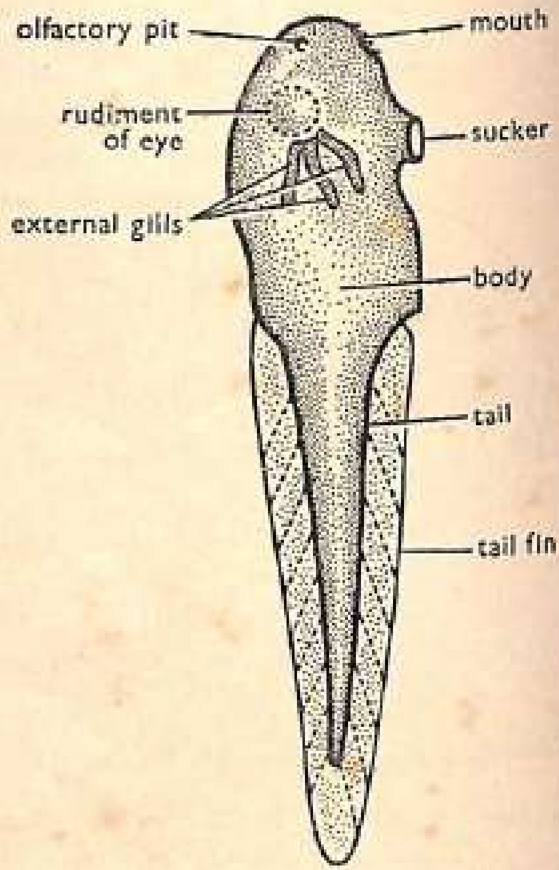


Fig. 5-4. Frog. Tadpole larva whole mount.

[5] FROG—T. S. of Tadpole through Eyes

Comments :

(1) Eyes are most conspicuous and protuberant structures and they begin to develop very early. Eyes develop from optic vesicles, which originate from a pair of diverticulae given from thalamencephalon on each side.

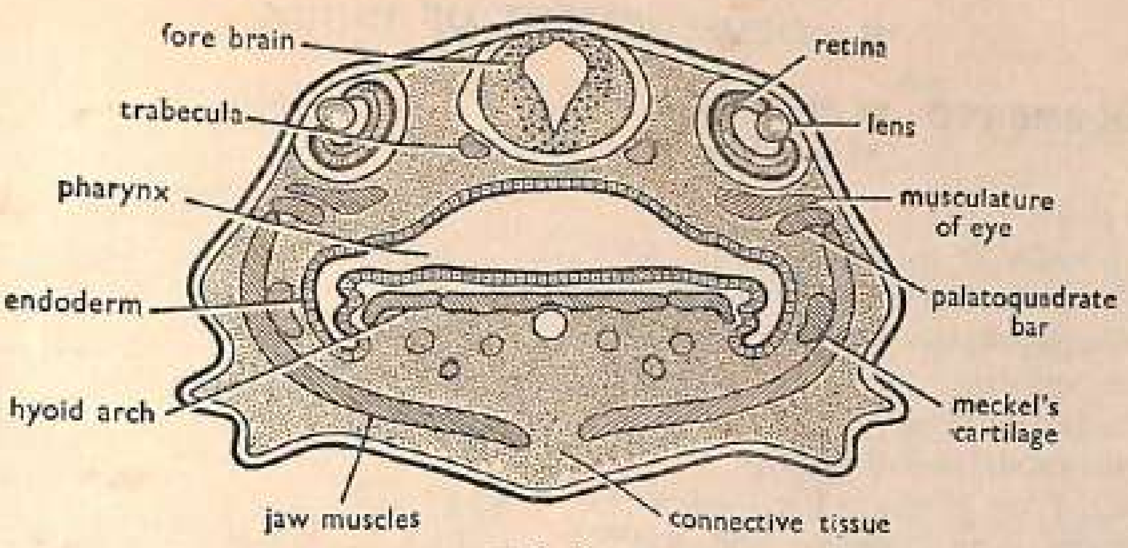


Fig. 5-5. Frog. T. S. of tadpole through eyes.

(2) The section shows a pair of large eyes on the sides of forebrain. Each eye is composed of eye muscles, lens and sensory layer of retina.

(3) Other structures seen in section are jaw muscles, large pharynx, palato-quadrate bar, Meckel's cartilage, epidermis, hyoid arch, connective tissue and epidermis.

[6] FROG—T. S. through Ears of Early Tadpole

Comments :

(1) Ears develop as a pair of auditory pits from the epiblast on the sides of hind brain.

(2) The auditory pits become vesicle like and enclose the middle ear. The semicircular canals develop as outgrowths from the wall of auditory vesicles.

(3) The auditory vesicles develop at early tadpole state and found on dorsal side of the section. Between two auditory capsules the medulla oblongata is situated, enclosing IV ventricle. Beneath medulla oblongata the notochord is present.

(4) The lower portion of the section contains large pharynx, laryngeal chamber, branchial arches and pericardium, enclosing developing auricle and ventricle.

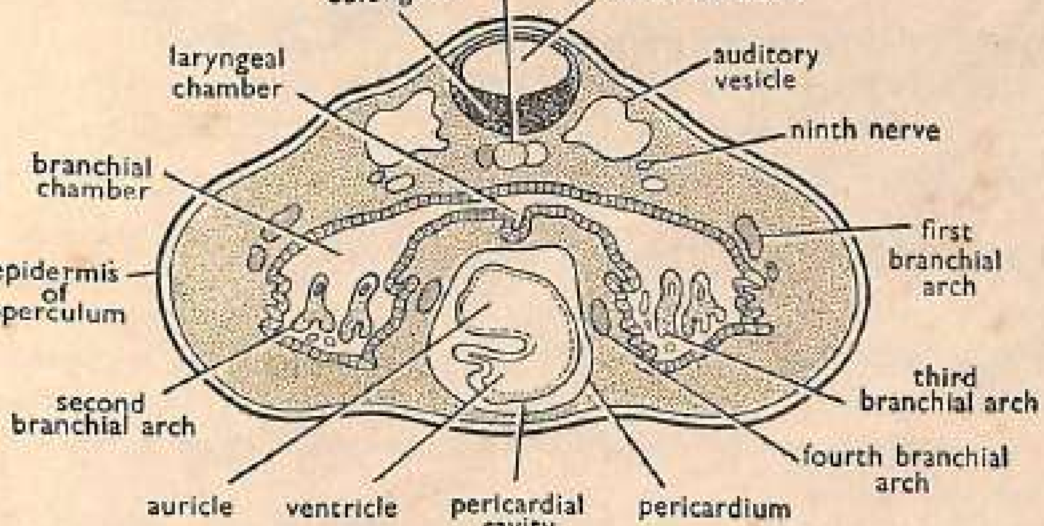


Fig. 5-6. Frog, T. S. through ears of early tadpole.

B. DEVELOPMENT OF CHICK

[7] CHICK-EMBRYO—W. M. 4 hours of Incubation

Comments :

(1) Four hours of incubation of the egg shows differentiation of the blastodisk into **area pellucida** and **area opaca**

(2) One quadrant of area pellucida becomes thickened, which marks the future caudal end of embryo.

(3) After 7 to 8 hours, the thickening becomes more elongated and represents start of primitive streak (Fig. 5-7).

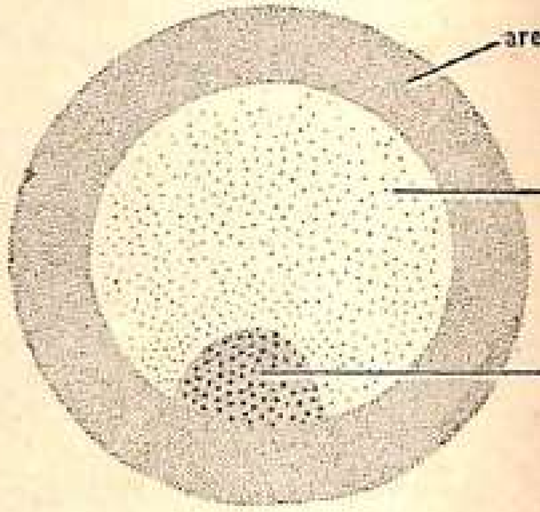


Fig. 5-7. Chick-embryo, 4 hours of incubation (whole mount).

[8] CHICK-EMBRYO—W.M. 16 hours

Comments :

(1) By 16 hours of incubation the primitive streak becomes so distinct that embryos are characterized as being in primitive streak stage.

(2) In fixed and stained slide, w.m. is composed of central furrow, called as **primitive groove** lined by thickened **primitive ridges.**

(3) At the cephalic end of the primitive streak, closely-packed cells form thickened area, called as **Hensen's node.** Part of area pellucida adjacent to the primitive streak shows increased thickness and forms embryonic area or embryonic shield.

(4) Area pellucida assumes elliptical shape.

(5) Elongated primitive streak represents long axis of future embryonic body.

(6) Caudal end of the streak is that which lies close to the area opaca.

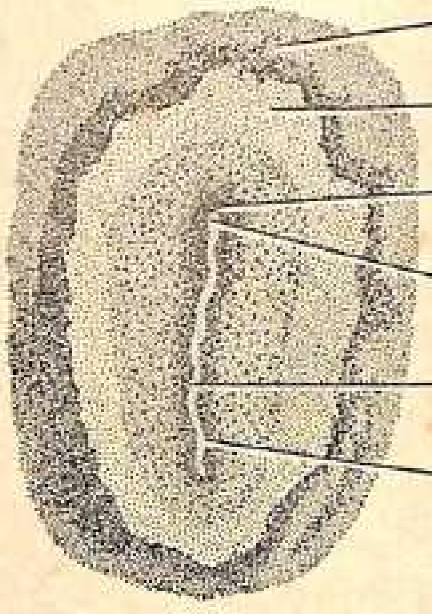


Fig. 5-8. Chick-embryo. 16 hours of incubation.

[9] CHICK-EMBRYO—L.S. of 17 hours Embryo

Comments :

(1) L. S. through 17 hours represents the stage shortly after primitive streak formation and it also marks the beginning of morphogenetic movement of cells to form notochord.

(2) The section shows ectoderm, Hensen's node, primitive pit, primitive groove, notochord and primitive gut.

(3) The mesoderm extends on either side between ectoderm and endoderm.

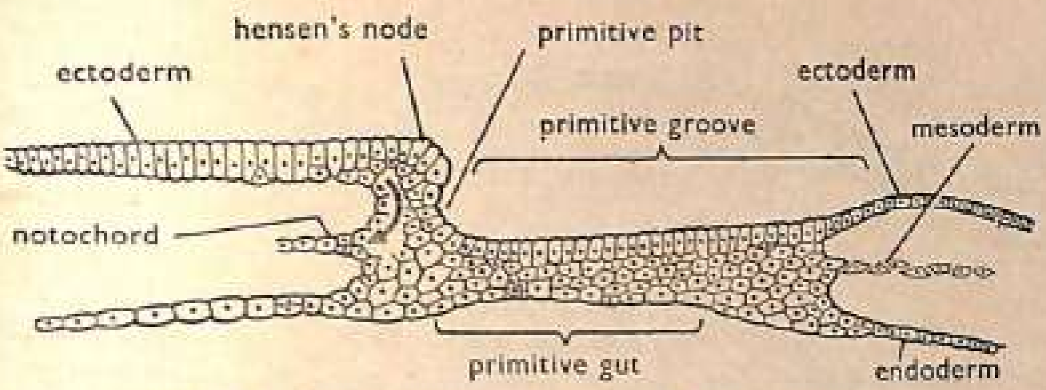


Fig. 5-9. Chick-embryo. L. S. of 17 hours of incubation.

[10] CHICK-EMBRYO—W. M. 18 hours

Comments :

(1) After 18 hours of incubation the notochord has become markedly elongated, forming a prominent structure.

(2) The notochord extends towards cephalic region in the mid-line from Hensen's node.

(3) 18 hours incubated embryo is spoken of as being in the head process stage.

(4) At the tip of the notochord neural plate develops.

(5) In front of notochord and neural plate there is a space called as pro-amnion.

(6) The embryonic area, area pellucida and area opaca become more prominent.

(7) The primitive streak gradually decreases in size.

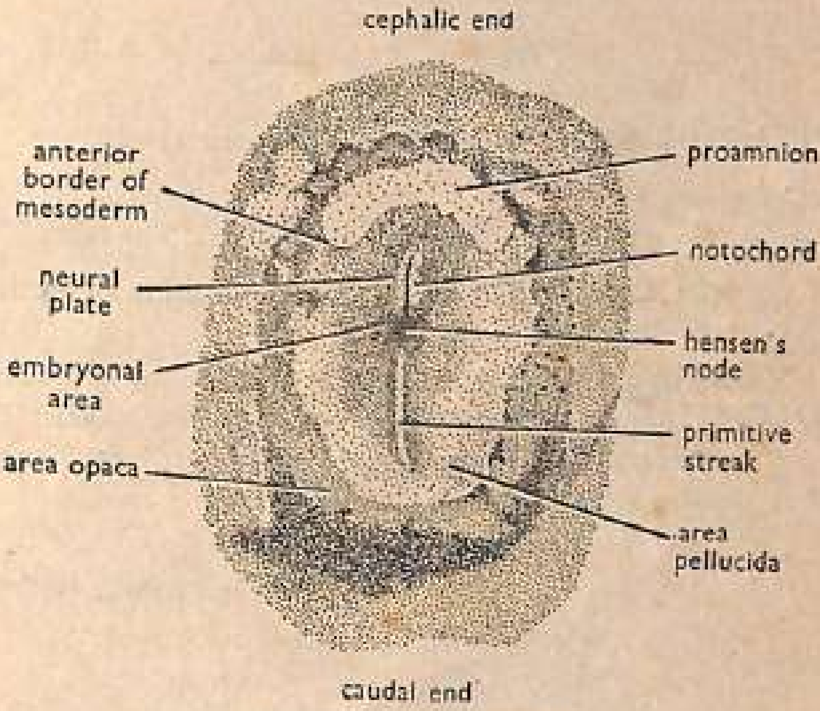


Fig. 5-10. Chick-embryo.
Whole mount of 18 hours of incubation.

[11] CHICK-EMBRYO—L. S. of 18 hours Embryo

Comments :

(1) The L. S. through 18 hours incubated embryo shows advanced inner structure about the germ layers.

(2) The ectoderm is vertically hatched, the cells of mesoderm are represented by heavy angular dots and endoderm is represented by stippling backed by a single line.

(3) Section A shows yolk, ectoderm of neural plate, notochord, mesoderm, ectoderm and endoderm of blastoderm. Section B shows yolk, endoderm, primitive pit, primitive ridge, mesoderm and primitive gut.

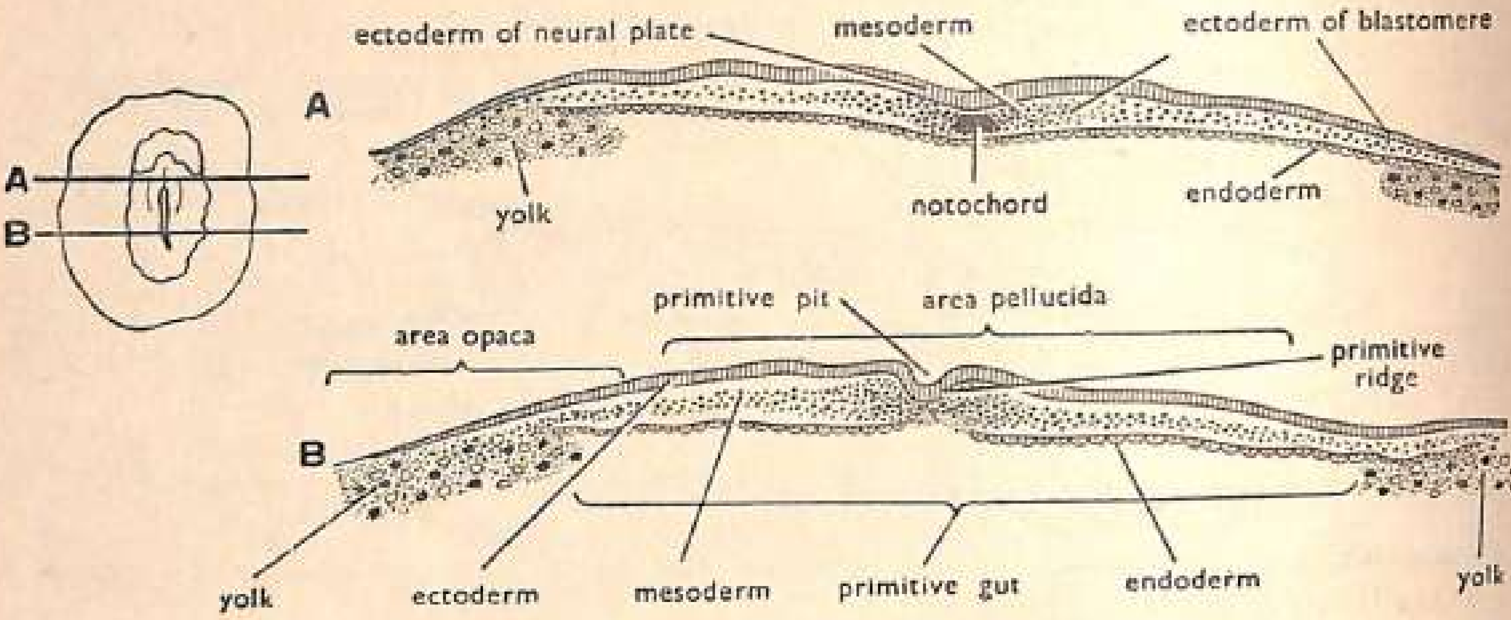


Fig. 5-11. Chick-embryo. A, B—L. S. of 18 hours of incubation.

[12] CHICK-EMBRYO—W. M. 24 hours

Comments :

(1) At 24 hours of incubation the folding of the neural plate is much more clearly marked. In stained and transparent preparation of entire embryo neural folds appear as a pair of dark bands.

(2) The neural folds at cephalic end are more prominent than at caudal end.

(3) Foregut is also established at this stage. The gut caudal to foregut is called as midgut and the opening from midgut into foregut, namely anterior intestinal portal, also appears.

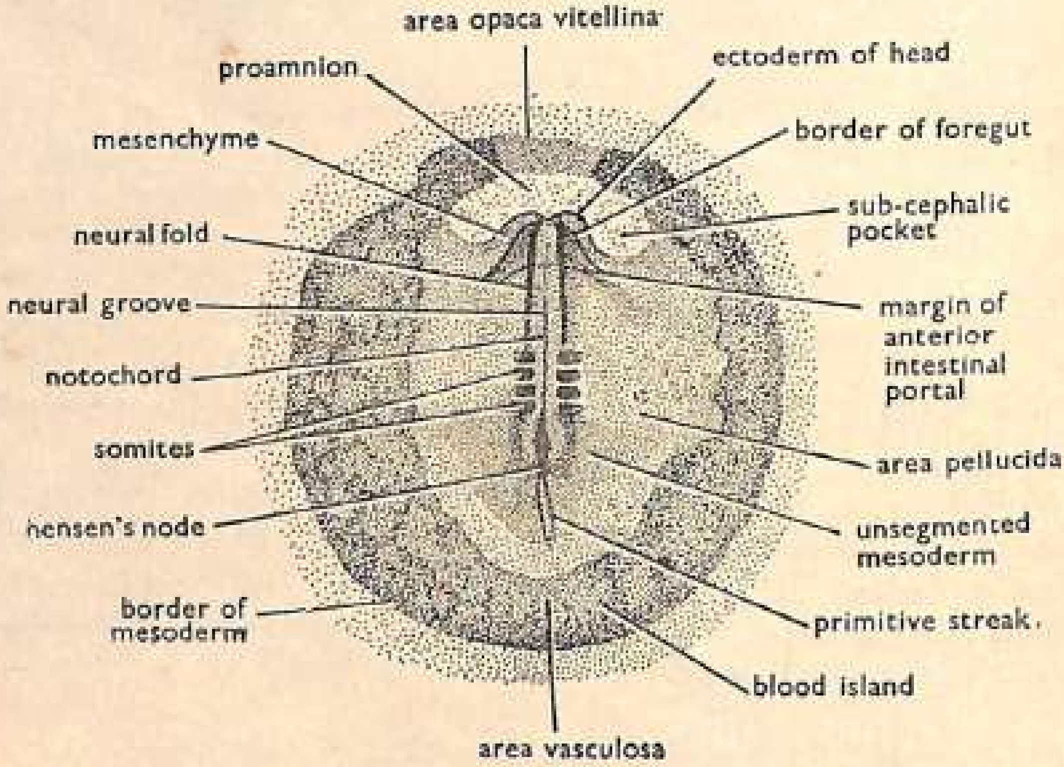


Fig. 5-12. Chick-embryo. Whole mount of 24 hours of incubation.

(4) In the middle, four pairs of somites are seen. The Hensen's node is pushed caudally and primitive streak is further reduced.

(5) The structures seen in the above sections are area opaca, vitelline, ectoderm of head, area pellucida, mesoderm, blood island, area vasculosa, notochord, mesenchyme and pre-amnion.

[13] CHICK-EMBRYO—T. S. of 24 hours Embryo

Comments :

A—T. S. through head :

(1) T. S. passing through head region shows neural plate folded to form a complete tube.

(2) Beneath neural fold is notochord.

(3) Other structures seen in section are mesenchyme, foregut, ectoderm of head, mesoderm and endoderm.

B—T. S. through mid-body :

(4) T. S. through mid-body shows formation of somites and changes in mesoderm.

(5) The mesoderm is differentiated into dorsal mesoderm, intermediate mesoderm and lateral mesoderm.

(6) Dorsal mesoderm forms somites, the lateral mesoderm differentiates into somatic and splanchnic layers and intermediate mesoderm forms nephrotomic plate.

(7) Other structures seen are ectoderm, endoderm, lateral margin of anterior intestinal portal, midgut and pericardial region of coelom.

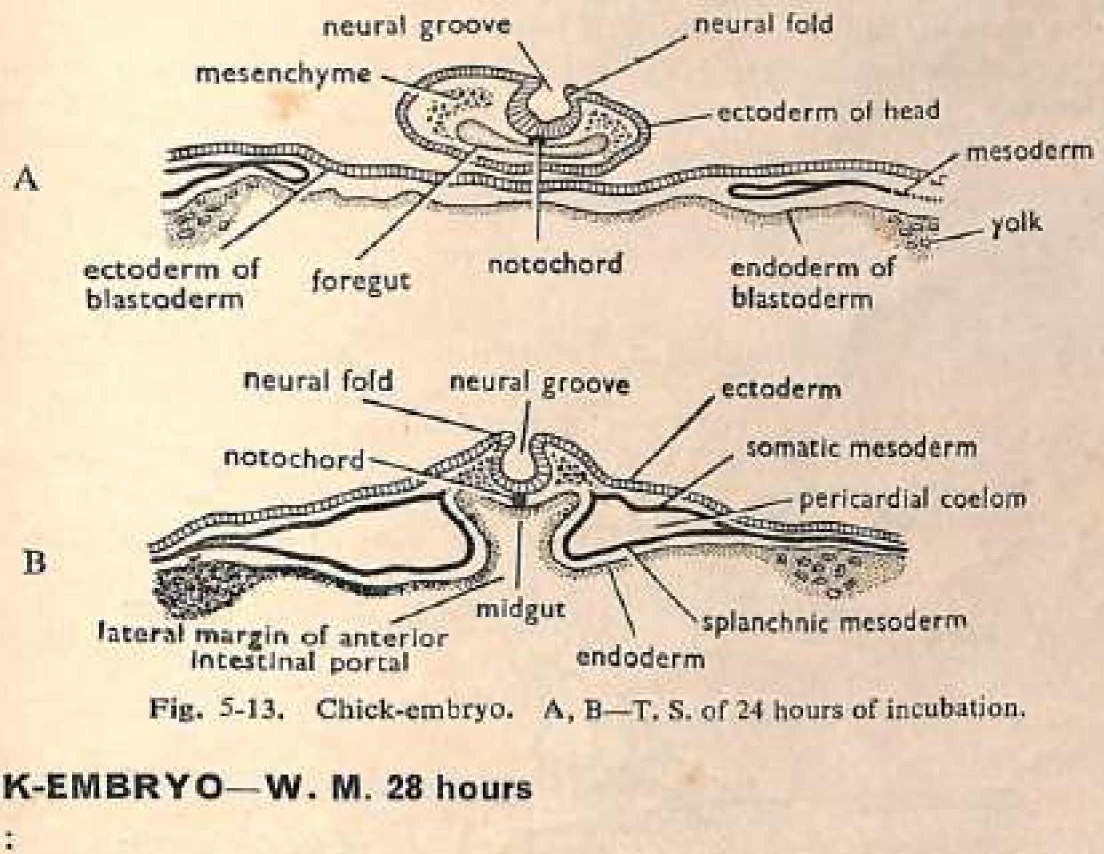


Fig. 5-13. Chick-embryo. A, B—T. S. of 24 hours of incubation.

[14] CHICK-EMBRYO—W. M. 28 hours

Comments :

(1) The entire embryo of 28 hours of incubation shows marked advances in the development of cephalic region.

(2) The neural folds completely fuse forming neural tube, which becomes completely separated from superficial ectoderm.

(3) Head projects free from blastoderm.

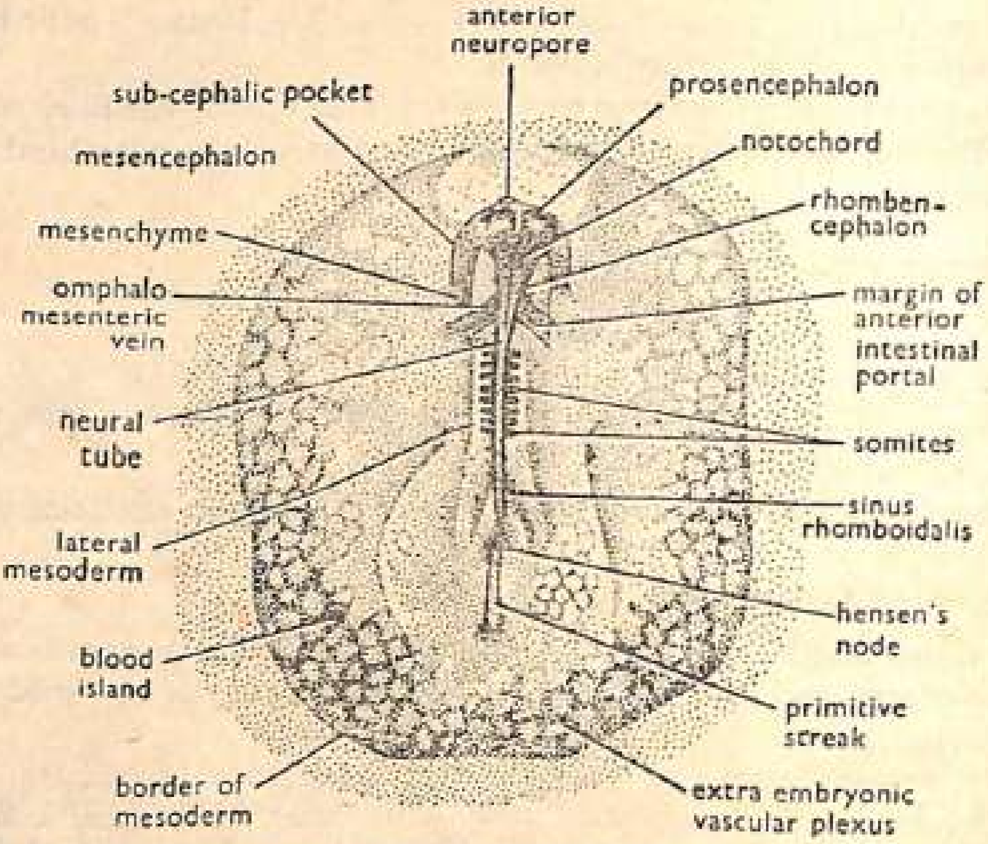


Fig 5-14. Chick-embryo. Whole mount of 28 hours of incubation.

(4) Three primary brain vesicles, namely prosencephalon (forebrain), mesencephalon (mid-brain) and rhombencephalon (hind brain) are differentiated.
(5) Eight pairs of somites develop. (6) Anterior neuropore still remains open.
(7) The Hensen's node still pushed back and primitive streak becomes much smaller.
(8) Other structures seen in section are anterior intestinal portal, extra-embryonic vascular plexus, blood island, omphalomesenteric vein and sub-cephalic pocket.

[15] CHICK-EMBRYO—T. S. of 28 hours Embryo

Comments :

(1) T. S. through 28 hours of incubation shows formation of heart from mesoderm.

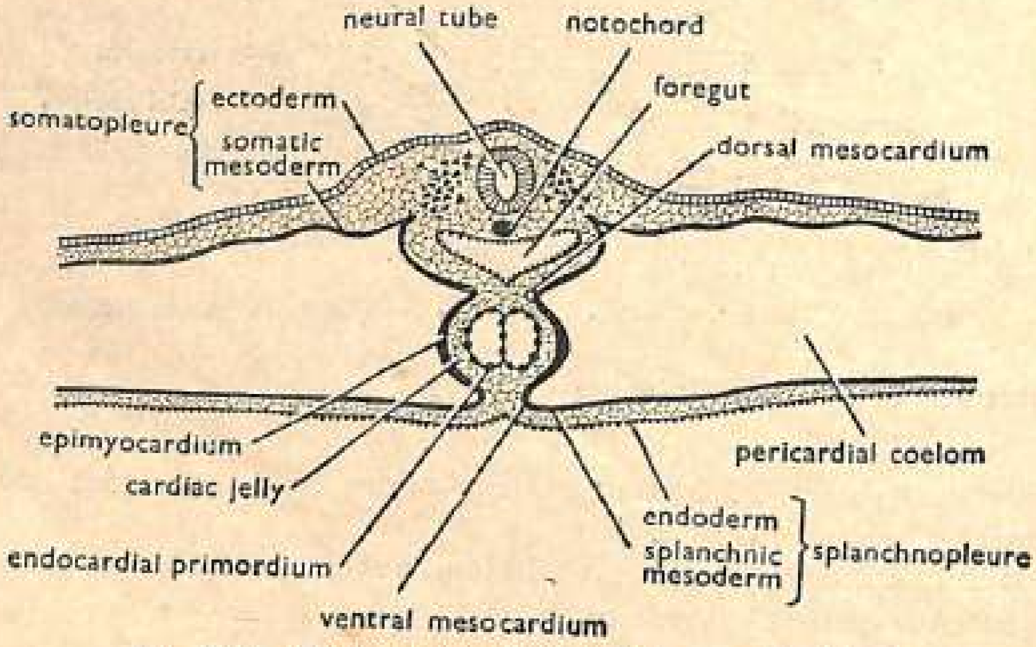


Fig. 5-15. Chick-embryo. T.S. of 28 hours of incubation.

(2) Epi-myocardium and endocardial primordium are clearly seen.
(3) The section also shows closed neural canal, notochord, line of fusion of margins of anterior intestinal portal, somatopleure, splanchnopleure and pericardial coelom.

[16] CHICK-EMBRYO—W. M. 33 hours

Comments :

(1) Thirty-three hours incubated embryo shows some of the fundamental steps in the formation of central nervous system and circulatory system.
(2) Various neuromeric enlargements form brain region.
(3) The optic vesicles are established as paired lateral outgrowths of the prosencephalon.
(4) Infundibulum is formed as a sort of depression in the floor of the prosencephalon.
(5) Twelve pairs of somites are formed.
(6) Mid-region of the heart is considerably dilated and bent to the right (Fig. 5-16).

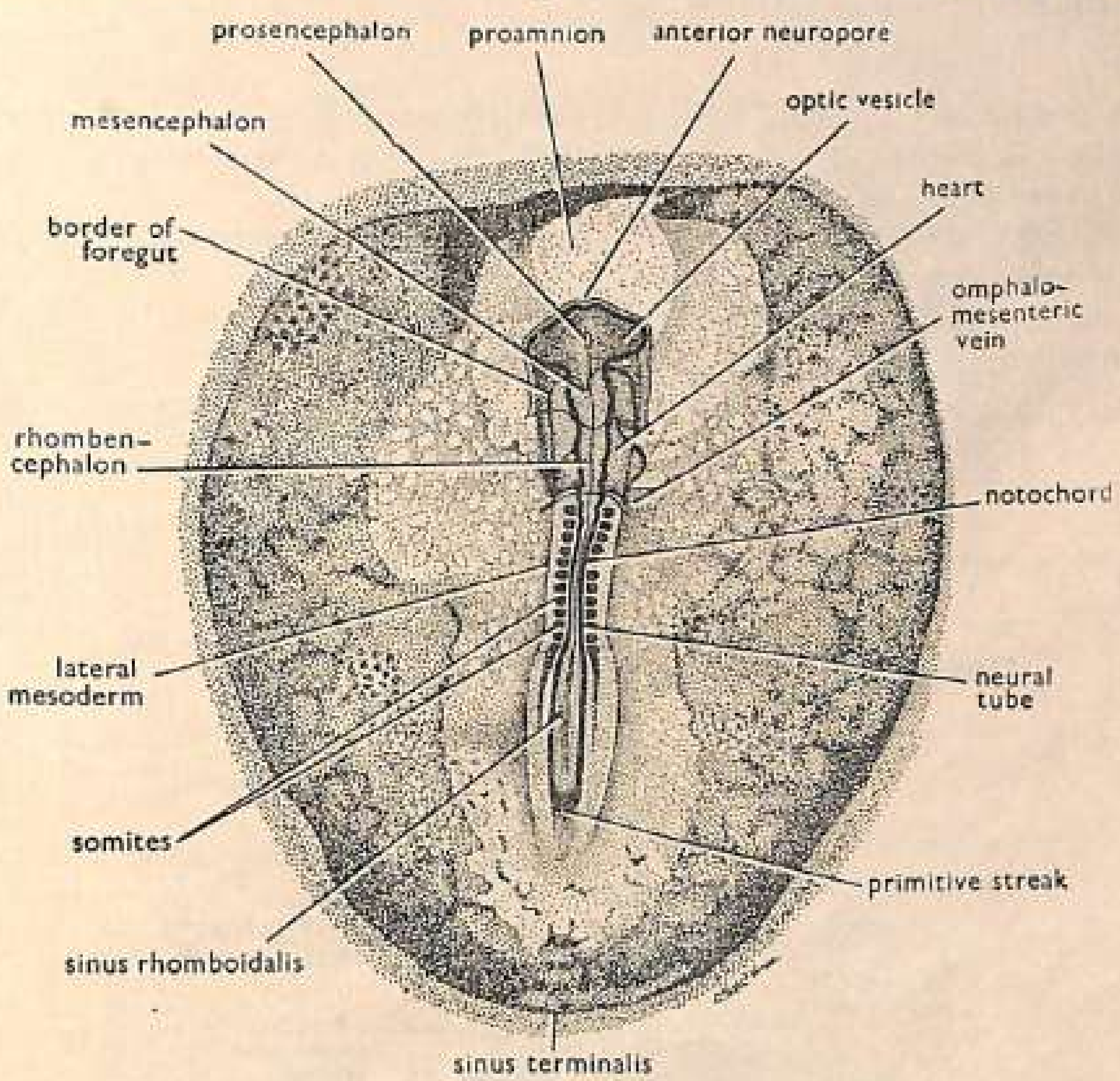


Fig. 5-16. Chick-embryo. Whole mount of 33 hours of incubation.

[17] CHICK-EMBRYO—T.S. of 33 hours Embryo

Comments :

(1) This section shows ectoderm, prosocoel, opticoel, mesenchyme, somatic mesoderm, splanchnic mesoderm and endoderm
(2) It shows mid-structure namely, mesocoel, anterior cardinal vein, dorsal aortic root, somatopleure, extra-embryonic coelom, splanchnopleure, foregut, notochord and ventral aortic root.

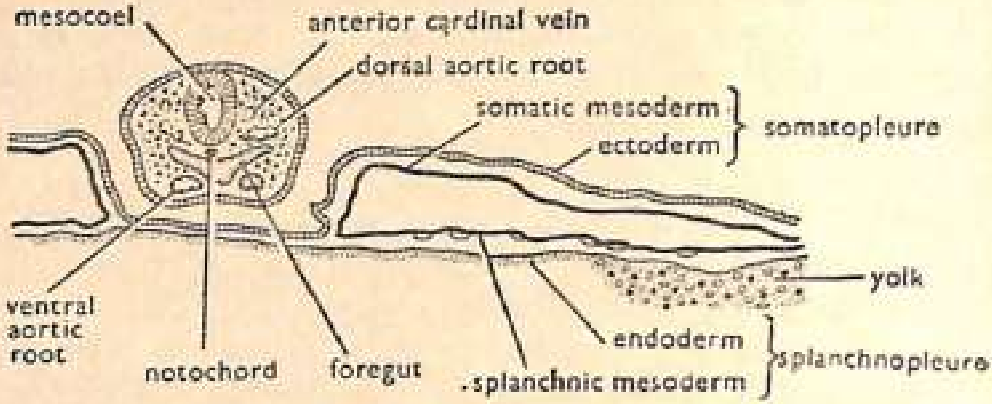


Fig. 5-17. Chick-embryo. T. S. of 33 hours of incubation.

[18] CHICK-EMBRYO—W. M. 43 hours

Comments :

(1) 43 hours incubated embryo shows cranial flexure and torsion. The cephalic region of embryo is twisted in such a way that left side comes to lie next to the yolk and right side away from yolk.

(2) The heart becomes chambered. It is differentiated into ventricular, arterial and sinus regions. Truncus arteriosus also develops.

(3) Auditory pit also makes its appearance.

(4) Vitelline vessels communicate with omphalomesenteric vein.

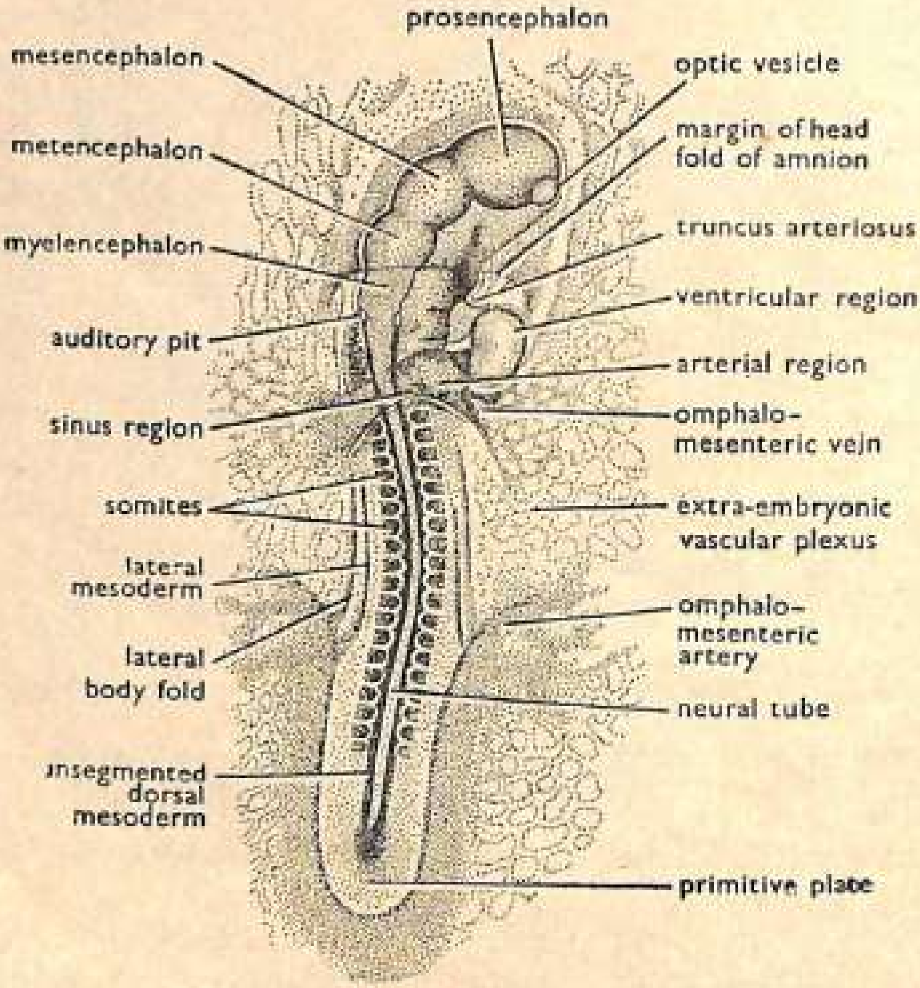


Fig. 5-18. Chick-embryo. Whole mount of 43 hours of incubation.

(5) Number of somites increases to 19. (6) Lateral body folds also develop.
(7) At 43 hours of incubation embryo develops rudiments of most of the organs.

[19] CHICK-EMBRYO—W. M. 72 hours.

Comments :

(1) After 72 hours of incubation, body is affected throughout by torsion and entire body is turned through 90°.
(2) Mid-body becomes concave. (3) Visceral arches develop.
(4) Mandibular arch forms caudal boundary of oral depression.
(5) Nasal pits appear as shallow depressions.
(6) Appendage rudiments also make their appearance. (7) Eye develops lens.

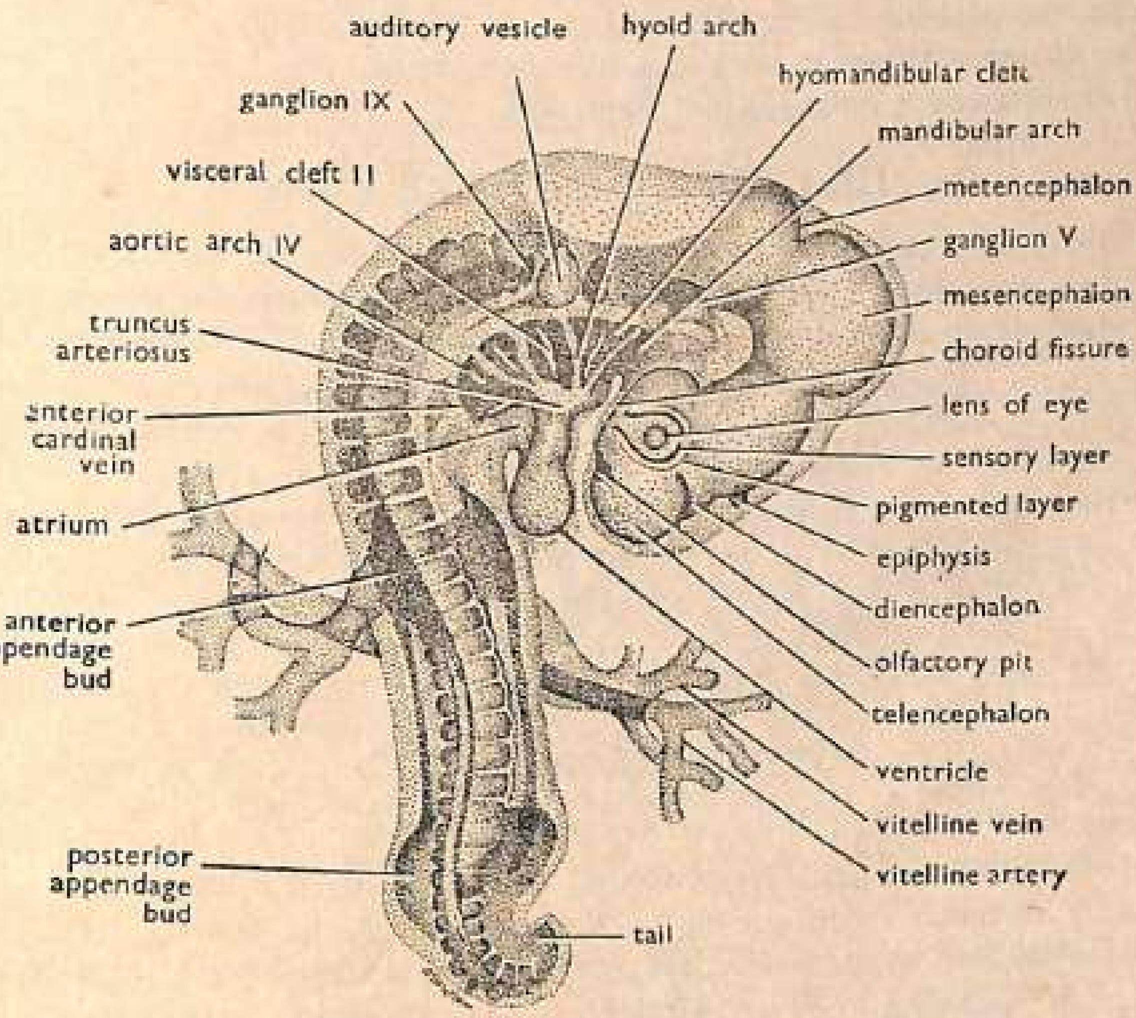


Fig. 5-19. Chick-embryo. Whole mount of 72 hours of incubation.

Chapter **6**

Comparative Osteology

(Study of Bones)

Although the term *skeleton* denotes the bones inside the body for a layman, yet for students of science we refer the internal framework as *endoskeleton*, which is derived from dermis. The endoskeleton is an important system inside the body. On the basis of endoskeleton, two distinct divisions in the Fauna have been made—one Chordata and the other Non-Chordata, with and without internal framework.

DIVISION OF ENDOSKELETON

Broadly the endoskeletal system is differentiated into :

(a) **Axial skeleton**—Consisting of 1 **skull**, 2. **vertebral column**, 3. **ribs** and 4. **sternum.**

(b) **Appendicular skeleton**—Consisting of 1. **Girdles**, and 2. **limb bones.**

The skeletal system may be studied in a comparative manner. The variation in structure and disposition of skeleton in different classes of vertebrates is so wide that individual study always brings about confusion. In order to remove this confusion, study of comparative osteology has been taken up. The four typical animals, namely frog (Amphibia), Varanus (Reptilia), fowl (Aves) and rabbit (Mammalia) have been used. For convenience, the following arrangement has been followed :

(a) Skull (dorsal, ventral and lateral views) and skull bones. (b) Vertebral column—different vertebrae. (c) Girdles—pectoral and pelvic. (d) Limb bones.

OSTEOLOGICAL TERMS

The following terms frequently come in the study of osteology :

(1) **Endoskeleton**—Internal framework of bones derived from dermis.

(2) **Axial skeleton**—Endoskeleton found along the axis of the body.

(3) **Appendicular skeleton**—Endoskeleton appended or added to axial skeleton and chiefly meant for limbs and girdles.

(4) **Vertebral column**—The original notochord in all vertebrates is broken into different units, called *vertebrae*, which are segmentally arranged.

(5) **Centrum, neural spine, neural arch and neural canal**—Structures found in vertebral column around spinal cord.

(6) **Pre-zygapophyses**—Articular processes by which vertebrae articulate with each other. Pre-zygapophyses are a pair of processes on the anterior face of vertebra.

(7) **Post-zygapophyses**—A pair of processes present on the posterior face of vertebra.

(8) **Transverse processes**—These are processes arising from the body of a vertebra or its neural arch. These are of the following types—

(a) **Diapophyses**—Transverse processes arising from the base of neural arch.

(b) **Parapophyses**—Transverse processes arising from the centrum.

(c) **Basapophyses**—Transverse processes arising from the ventro-lateral sides of centrum.

(d) **Pleurapophyses**—Transverse processes arising from the middle of arch.

(e) **Hypapophyses**—These are processes arising from the median ventral position of centrum.

(f) **Metapophyses**—These are the two outgrowths arising just above pre-zygapophyses.

(g) **Anapophyses**—These are slender transverse processes arising from just below the post-zygapophyses.

(h) **Zygospheres**—A pair of wedge-shaped processes present anteriorly on neural arch.

(9) **Acetabulum**—A cup-shaped cavity in pelvic girdle.

(10) **Acrocoracoid**—Found in birds, are additional processes present dorsally on the coracoid.

(11) **Acromian**—Found in mammals, a vertical process of scapular spine.

(12) **Synovial cavity**—Cavity between two articulating bones or cartilages.

(13) **Articular disc**—A pad of fibro-cartilage separating two articulating bones.

(14) **Joints**—Gap between two articulating bones or cartilages.

(15) **Immovable joints**—Joints between skull bones of fibrous nature.

(16) **Movable joints**—Ball and socket joints.

(17) **Condyle**—A ball-like swelling at the end of a bone for articulation.

(18) **Deltoid ridge**—A triangular and flattened outgrowth at the head of humerus for muscle attachment.

(19) **Asterospondylous**—The calcified area, star-like in centra.

(20) **Cyclospondylous**—The calcified area, centrally placed in centra.

(21) **Tectospondylous**—The central calcified area alternates with fibrous material.

(22) **Procoelus**—Centrum concave in front and convex behind.

(23) **Opisthocoelus**—Centrum convex in front and concave behind.

(24) **Chondrocranium**—Comprises of cartilaginous cranium (brain box) and cartilages of sense capsules.

(25) **Splanchnocranium**—Series of cartilaginous arches supporting visceral clefts forming jaw skeleton.

(26) **Dermocranium**—Dermal bones of skull.

(27) **Amphistylic**—Double suspension. Upper jaw is directly attached to otic region of cranium and the hyomandibular cartilage is movably attached to the otic region.

(28) **Autodiastylic**—It was found in extinct fishes in which upper jaw was attached to cranium by ligaments.

(29) **Autostylic**—Upper jaw fused with cranium. It is of the following types—

(a) **Holostylic**—Upper jaw fused with cranium and hyoid arch free from cranium—e.g., in Holocephali.

(b) **Autosystylic**—Lower jaw articulates with quadrate part of upper jaw. Hyoid arch and hyomandibular do not take part in suspensorium—e.g., in Lung-fishes.

(c) **Methystylic**—The symplectic bone derived from hyomandibular is attached to quadrate bone.

(d) **Craniostylic**—Lower jaw directly articulates with a membrane bone, the squamosal of osteocranium. The quadrate forms incus and articular malleus of ear ossicle—e.g., mammals.

(30) **Hyostylic**—Upper jaw suspended by ligament to cranium and hyomandibular is movably articulated to otic region of cranium.

While comparing special features of skulls of Amphibia, reptiles, birds and mammals, the skulls of Amphibia and mammals are compared together being **dicondylic**, while those of reptiles and birds are put together being **monocondylic**.

COMPARISON OF SKULLS OF FROG AND RABBIT

Skull of Frog	Skull of Rabbit
1. Skull is triangular in shape, broad and dorso-ventrally flattened.	1. Skull has narrow anterior end and broad posterior end. No dorso-ventral flattening.
2. The tadpole chondrocranium persists in adult to a greater extent. Sense capsules and cranium are largely made up of cartilage.	2. The original chondrocranium is completely replaced by ossified bones in adult. The cranium and sense capsules are made up of bones.
3. Cranium is smaller due to small size of brain and dorsally-placed orbits.	3. The cranial part is smaller but facial part is elongated. The orbits are laterally placed.
4. Dicondylic—two occipital condyles.	4. Dicondylic—two occipital condyles.
5. Platybasic-skull — The inter-orbital septum is absent and so the cranium extends beyond orbits.	5. Tropibasic—the inter-orbital septum is present and so the brain box does not extend into orbits.
6. Sphenethmoid constitutes posterior wall of olfactory chambers. Basi- ali- orbito- and pre-sphenoids, and supra- and basi-occipitals are absent.	6. Pre-frontal, post-frontal, parasphenoid, quadrato-jugal absent, while pterygoids are much reduced.
7. The floor of brain box is formed by parasphenoid and roof by fronto-parietals.	7. The floor of brain box is formed by basi-sphenoid and pre-sphenoid while roof by parietals and frontal.
8. Vomers and vomerine teeth present.	8. Vomers and vomerine teeth are absent. The pre-maxillae bear thecodont and diphyodont teeth and dentaries contain heterodont teeth.
9. Occipital region made up of ex-occipitals.	9. Occipital region made up of 2 exoccipitals, basi-occipital and supra-occipital.
10. Tympanic bulla is absent. Tympanic is ring-like.	10. Tympanic bone forms tympanic bulla.
11. Jaw suspensorium is **autostylic**, in which lower jaw is attached to skull through rod-like cartilaginous quadrate.	11. Jaw suspensorium is **craniostylic**—the mandible articulates with squamosal of cranium.

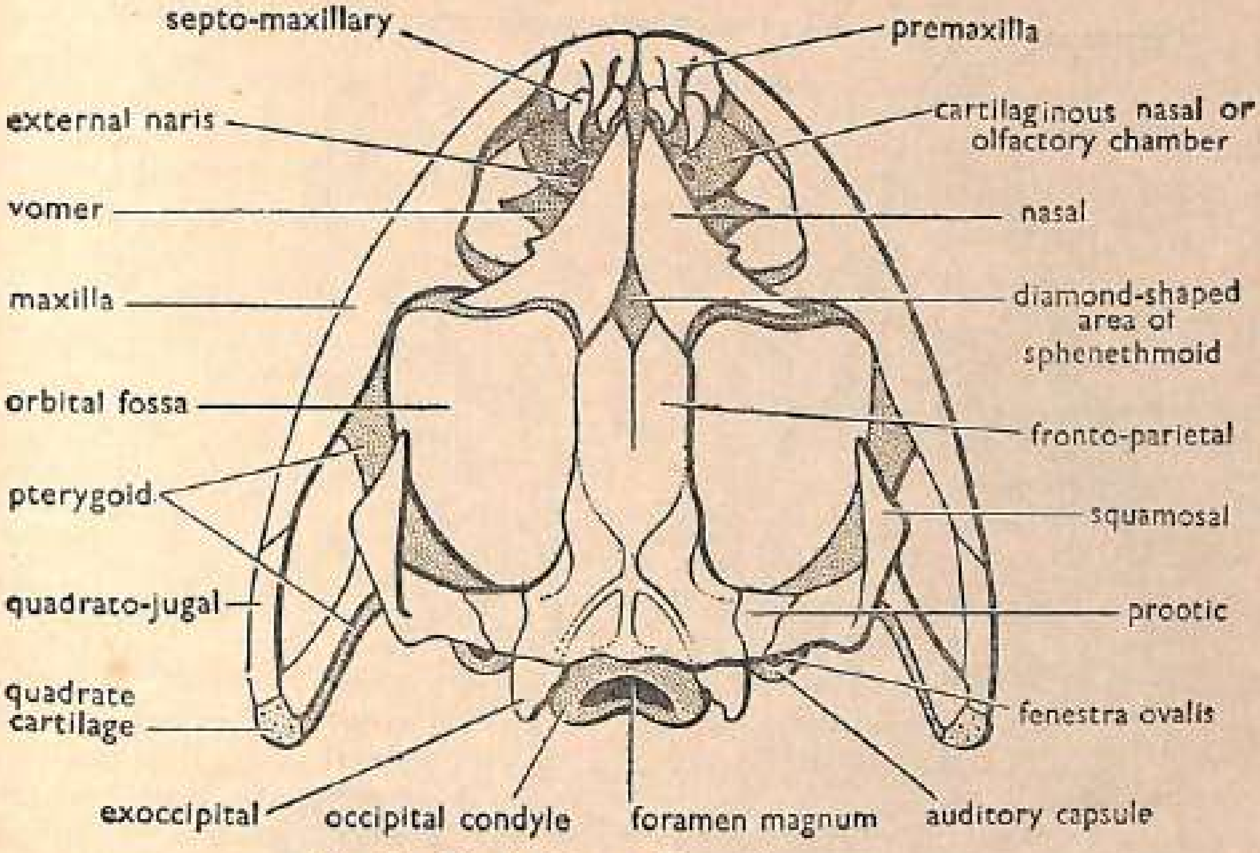


Fig. 6-1. Skull of Frog. Dorsal view.

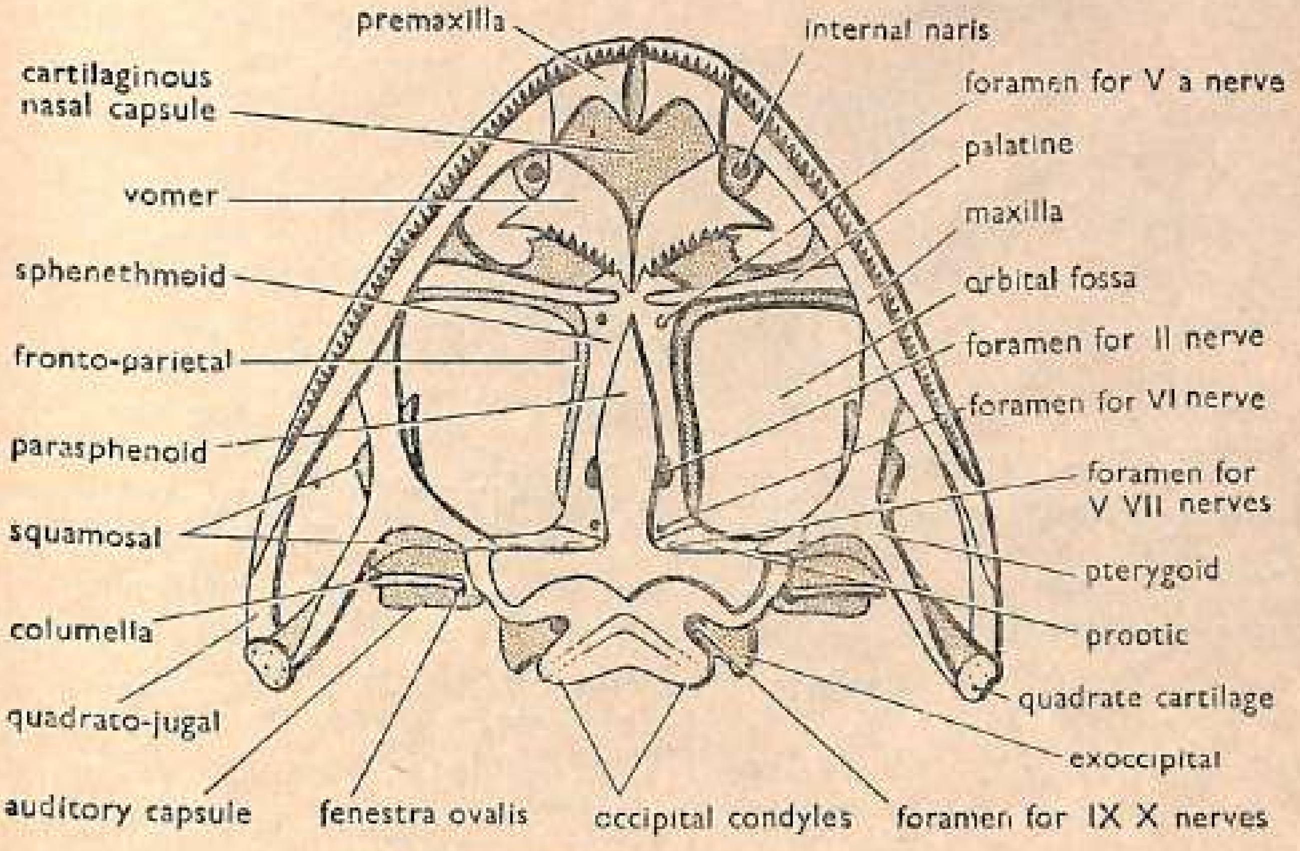


Fig. 6-2. Skull of Frog. Ventral view.

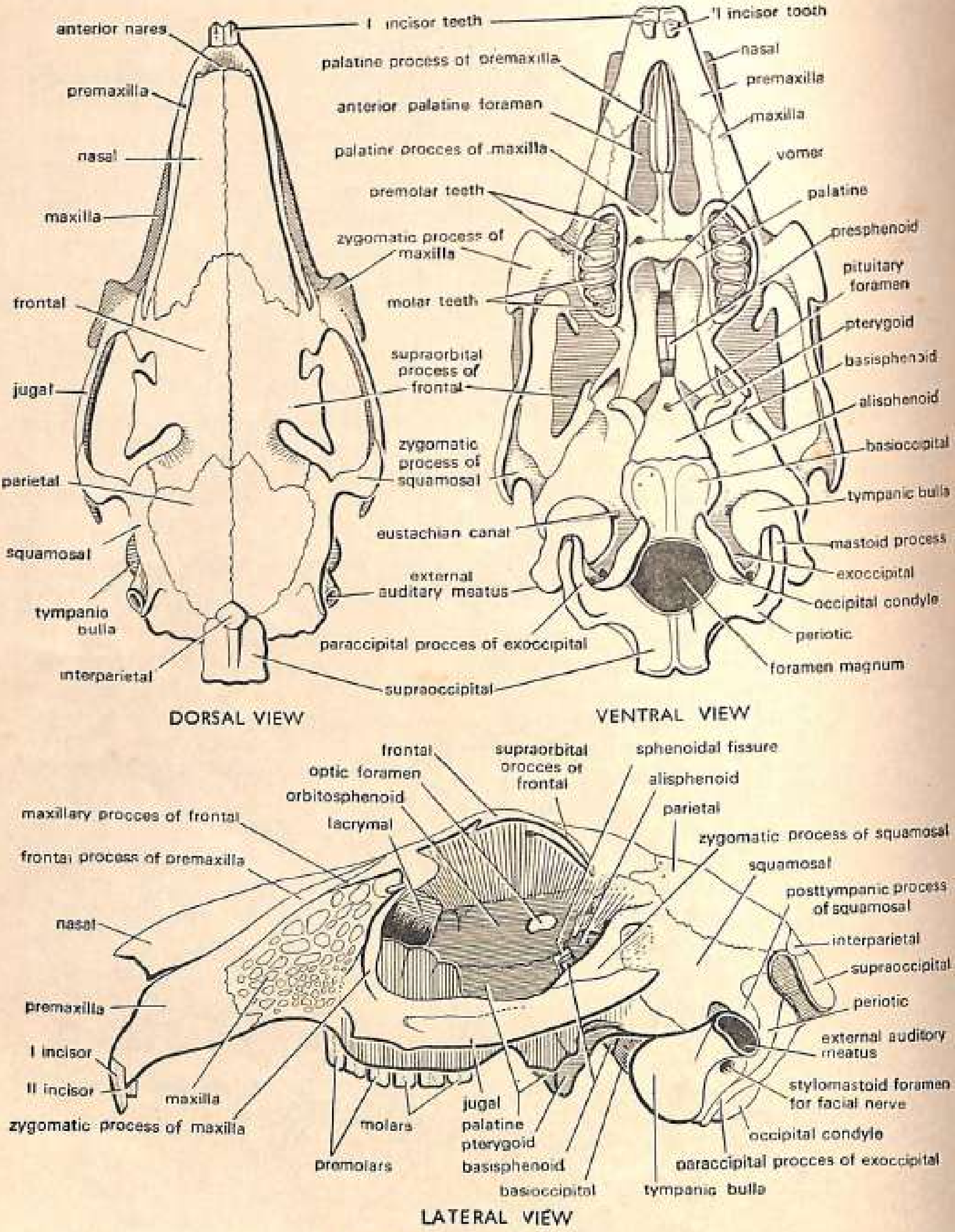


Fig. 6-3. Skull of Rabbit.

COMPARISON OF SKULLS OF VARANUS AND FOWL

Skull of Varanus	Skull of Fowl
1. The chondrocranium is well ossified. The skull is complicated and possesses several replacing and investing bones. The skull has considerable weight.	1. The skull is compact and devoid of teeth. It is very light due to the spongy bones and presence of air cavities. The lightness is in accordance with flying habit.
2. Beak absent. Jaw bones possess teeth.	2. *Distinct* feature of skull is the presence of a long-pointed beak without teeth.
3. Skull bones are several, unpolished and with *distinct sutures*.	3. Skull bones are very compact, closely fused, polished and with *obliterated sutures*.
4. Cranium is small.	4. The cranium is greatly enlarged to accommodate the large brain.
5. Monocondylic skull—single occipital condyle on the basi-occipital, which articulates with atlas vertebra.	5. *Monocondylic*—Single occipital condyle articulates with atlas in such a way that skull can move freely sidewise.
6. Skull **tropibasic**—the vertical inter-orbital septum separates comparatively smaller orbits.	6. Skull **tropibasic**—the definite inter-orbital septum separates large-sized orbits.
7. Pre-frontal, supra-orbital, post-orbital, parasphenoid, lacrymal and transverse bones present. The parietals fuse together forming a single bone and perforated by parietal foramen.	7. The supra-occipital joins with parietal and forming a large prominent ridge known as occipital or **lamboidal ridge.**
8. Tympanic cavity is small containing a single ear ossicle, the columella.	8. Tympanic cavity is large, hemispherical and having a single columella.
9. Teeth are polyphyodont, homodont, pleurodont and found on pre-maxillae, maxillae and dentaries.	9. Teeth absent. The palate is schizo-gnathous formed by vomers, palatines, pterygoids and palatal prolongations of maxillae.
10. Suspensorium autostylic.	10. Suspensorium autostylic.

DISARTICULATED SKULL BONES OF FROG

The disarticulated skull comprises of occipital region, fronto-parietals, sphenethmoid, parasphenoid, columella, nasals, septo-maxillaries, vomers, pre-maxilla, maxilla, quadrato-jugal, quadrate, palatine, squamosal, pterygoid, Mento-Meckelian, angulo-splenial and dentary.

1. **Occipital region**—(a) It is the posteriormost part of the skull and is formed by fronto-parietals on dorsal side, parasphenoid on ventral side and a pair of cartilaginous ex-occipitals, which enclose a large opening called *foramen magnum*. (b) The spinal cord passes through the foramen magnum. (c) Each ex-occipital contains a condyle,

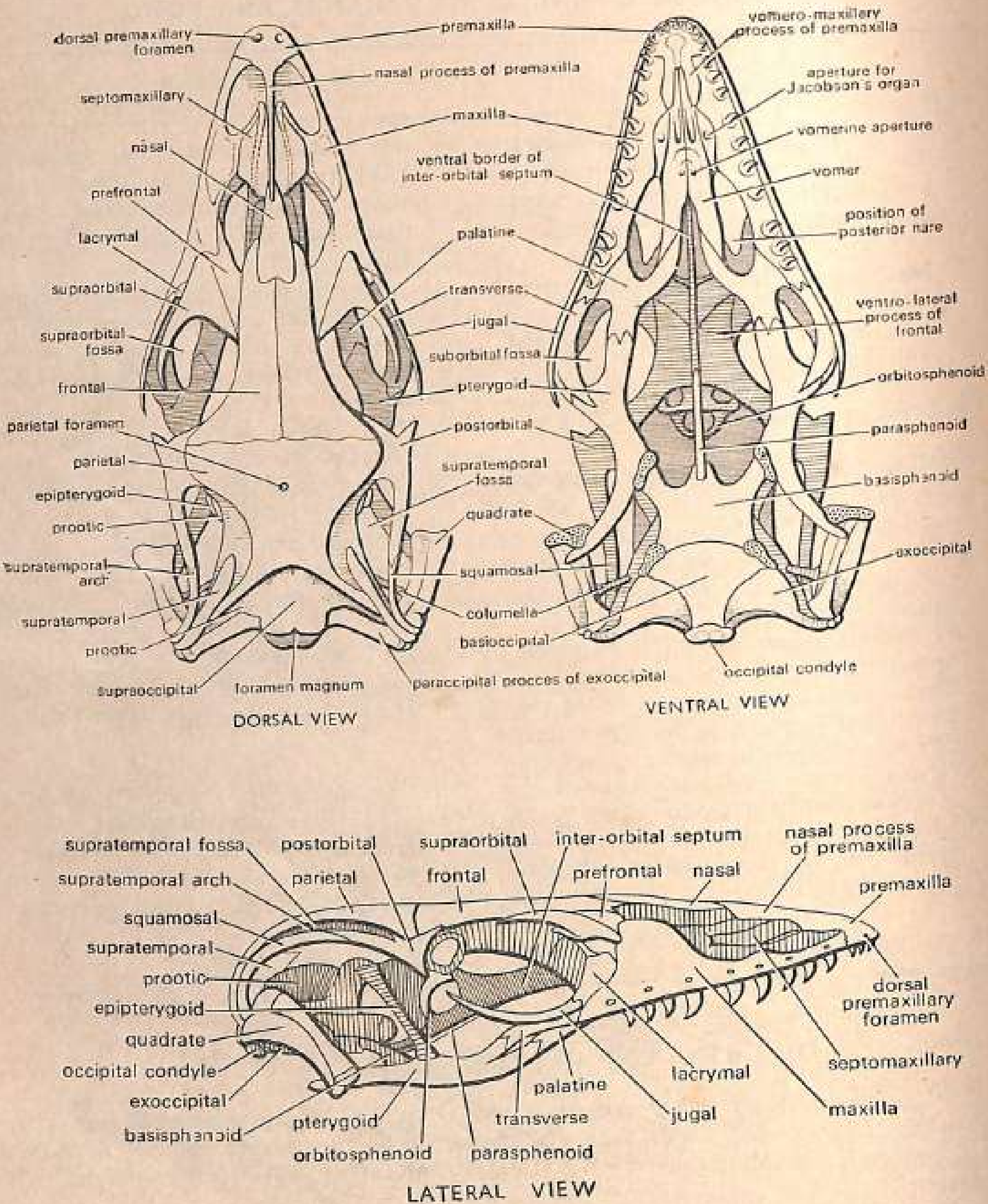


Fig. 6-4 Skull of *Varanus*.

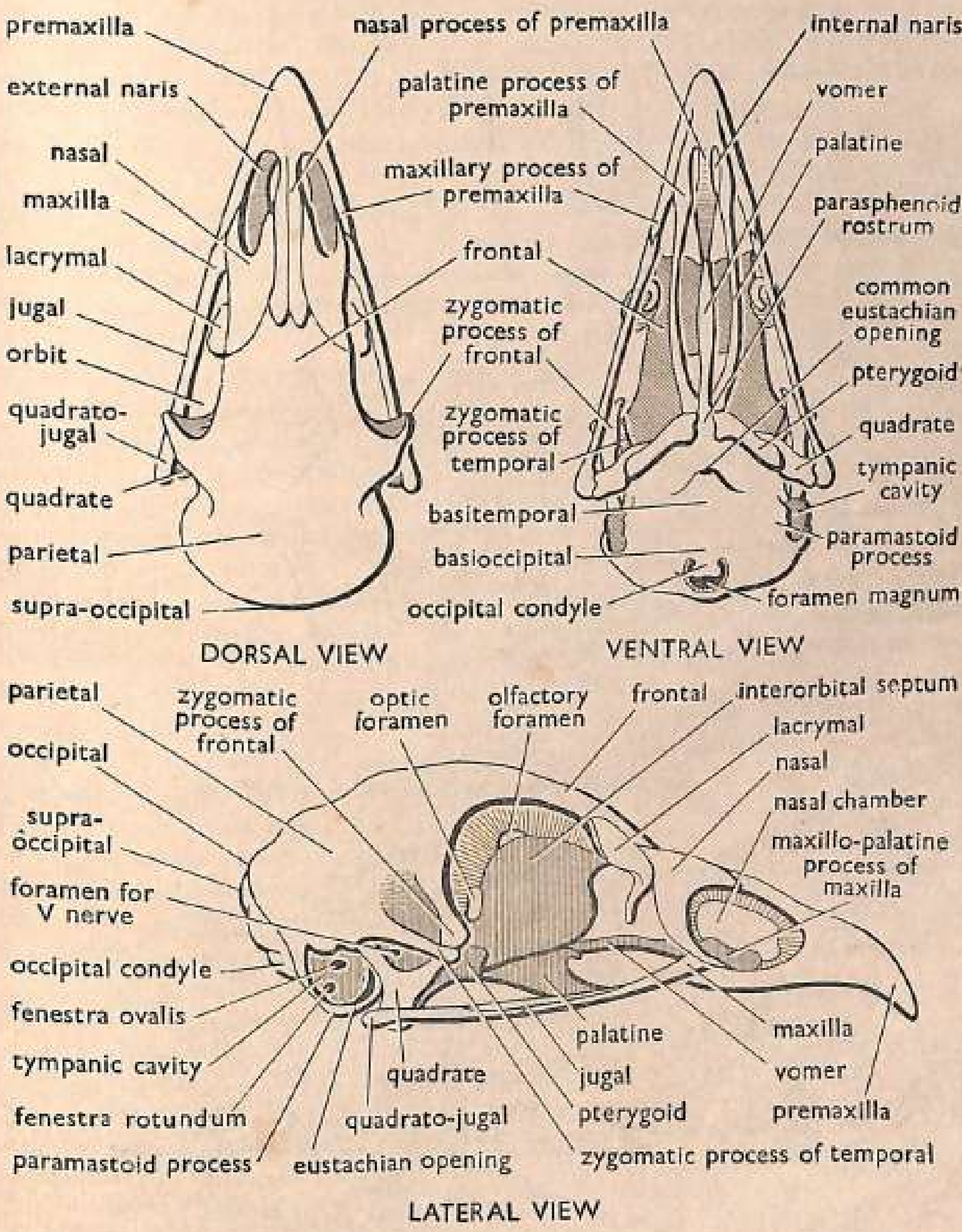


Fig. 6-5. Skull of Fowl.

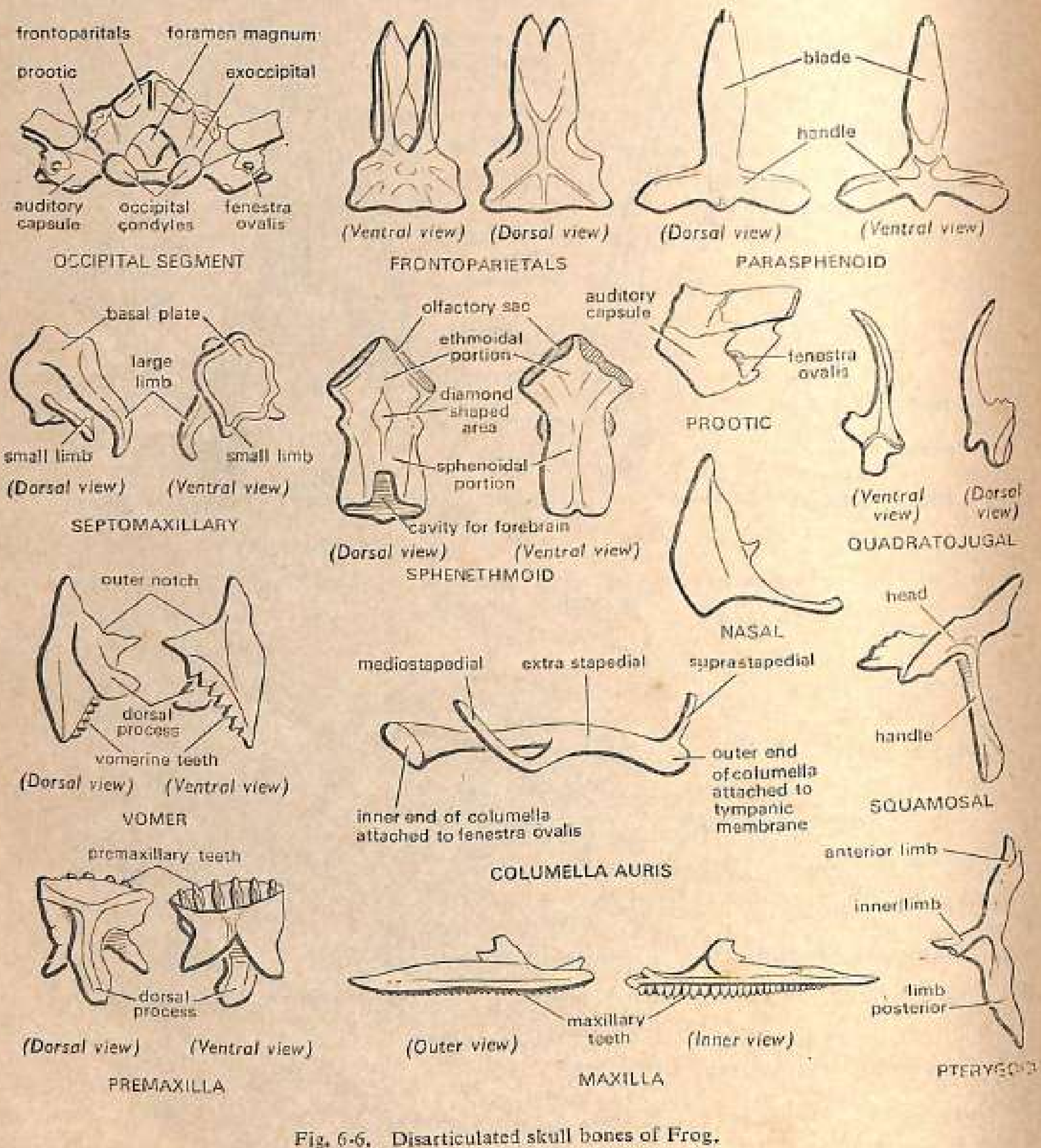


Fig. 6·6. Disarticulated skull bones of Frog.

which articulates with a facet on atlas vertebra. (d) Supra-occipital and basi-occipital absent. (e) Externally each ex-occipital is fused with cartilaginous auditory capsule, which is perforated by a minute opening, called as *fenestra ovalis*. (f) Anteriorly, each auditory capsule is formed by a cartilaginous bone, called as pro-otic.

2. **Fronto-parietals**—(a) These form a pair of long and broad membranous bones, which are united in mid-dorsal line and cover entire brain box. (b) In embryonic condition, frontal and parietal are separate but in adult they are completely fused. (c) They extend up to sphenethmoid anteriorly and up to ex-occipitals posteriorly.
3. **Sphenethmoid**—(a) It is a hollow tubular bone, surrounding anterior end of the cranial cavity and can be seen only on sides. (b) It is demarcated into anterior ethmoidal region and posterior sphenoidal region by a transverse partition. The ethmoidal region is further divided into right and left regions by a longitudinal division and each region encloses an olfactory sac. The sphenoidal region contains forebrain. (c) Major part of the bone is concealed dorsally by 2 nasals and fronto-parietals and ventrally by parasphenoid.
4. **Parasphenoid**—(a) Parasphenoid is like a dagger in the form of inverted "T" covering entire floor of cranium. (b) The upper blade-like part extends up to the sphenethmoid, while side portion or handle extends up to auditory capsules.
5. **Columella**—(a) The tympanic cavity has a rod-like middle ear bone called **columella auris**, the outer end of which is attached to the tympanic membrane and inner end is inserted on the outer wall of auditory capsule. (b) Columella conducts sound vibrations up to inner ear located in the head.
6. **Nasals**—(a) These form a pair of large triangular, flattened and membranous bones, which serve as roof of olfactory capsules. (b) Nasals are united in median line. (c) Anteriorly, they extend up to pre-maxillae and posteriorly, they meet with fronto-parietals and leave a diamond-shaped area before meeting.
7. **Septo-maxillary**—(a) It is an irregularly-shaped small bone, associated anteriorly with nasal. It is composed of a basal plate and two unequal processes.
8. **Vomers**—(a) They are membranous bones covering the floor of the olfactory capsules. (b) Each vomer is triangular in shape, lining the posterior nostrils and containing 6–7 minute vomerine teeth along postero-lateral margin.
9. **Pre-maxilla**—(a) It is found in upper jaw at the tip of snout and it articulates with maxilla on each side. (b) It is a small irregular bone, having a few conical pre-maxillary teeth along anterior lower margin, and dorsally a backwardly directed process partly forms inner boundary of external nostril.
10. **Maxilla**—(a) It constitutes major part of upper jaw. (b) It is a thin, elongated, slightly curved bone joined behind by quadrato-jugal. (c) It also articulates partly with palatine and pterygoid. (d) Maxilla is provided with several backwardly-directed, conical and pointed teeth.
11. **Quadrato-jugal**—(a) It is easily recognized by being comma-shaped and is found behind maxilla, forming posterior outer region of upper jaw. (b) Its posterior region is broadened and articulates with quadrate cartilage.
12. **Quadrate**—(a) It is a rod-shaped suspension cartilage, which connects mandible with skull. (b) Internally it is fused with auditory capsule and posteriorly attached to hind end of quadrato-jugal. (c) It is completely concealed under pterygoid and squamosal.
13. **Palatine**—(a) It lines the antero-ventral side of each orbit. (b) It is a long, delicate, transverse and rod-shaped bone, connecting anterior cranium with middle maxilla.

14. **Squamosal**—(a) It attaches with the posterior end of cranium on dorso-lateral side above pterygoid and it also forms postero-dorsal margin of its orbit. (b) It is a hammer-shaped or T-shaped bone, having a free anterior limb and two short limbs, which are attached to auditory capsule and pro-otic.
15. **Pterygoid**—(a) It is a Y-shaped and three-rayed bone attached laterally to the posterior end of cranium. It also forms postero-ventral margin of orbit. (b) The anterior ray joins with outer end of palatine and maxilla, while posterior ray joins with quadrato-jugal and quadrate and inner ray articulates with parasphenoid and auditory capsule.

DISARTICULATED SKULL BONES OF RABBIT

The disarticulated skull bones of Rabbit include occipital region, squamosal, parietal, interparietal, basisphenoid and alisphenoids, pre-sphenoid and orbitosphenoids, frontal, nasal, vomer, turbinals, peri-otic and tympanic bulla. The jaw bones are pre-maxilla, maxilla, jugal, pterygoid, palatine and dentary.

1. **Occipital region**—(a) It encloses a large **foramen magnum** and is made up of supra-occipital, ex-occipital and basi-occipital cartilaginous bones. (b) The supra-occipital forms a squarish bulging and gives a pair of processes for muscle attachment and articulates with interparietal, parietals, squamosal and peri-otics. (c) The ex-occipitals bear occipital condyles and also give downwardly-directed para-occipital processes. (d) The basi-occipital forms the floor and it articulates with basisphenoid in front and with peri-otics laterally.
2. **Squamosal**—(a) It is a more or less rectangular membrane bone found ventral to parietal. (b) It gives a backward process called post-tympanic process over peri-otic and external auditory meatus. (c) The outer surface contains zygomatic process and undersurface contains a mandibular facet for articulation with condyle of lower jaw.
3. **Parietal**—(a) It forms major part of posterior cranial roof. (b) Parietals are demarcated from alisphenoids by squamosals and they remain united mid-dorsally by a distinct suture. (c) Posteriorly each parietal gives a ventral process.
4. **Inter-parietal**—It is a triangular membrane bone between parietals and supra-occipital.
5. **Basisphenoid and alisphenoids**—(a) Both constitute a compound bone. (b) Basisphenoid is a flattened, triangular and median cartilaginous bone articulating with basi-occipital. It also contains a depression meant for pituitary gland and is perforated by a minute pituitary foramen. Basisphenoid articulates with pre-sphenoid in front and laterally with alisphenoids. (c) The alisphenoids are closely and obliquely applied on either side of basisphenoid. They are wing-shaped and contain three parts.
6. **Pre-sphenoid and orbitosphenoids**—(a) They form compound bones. (b) Pre-sphenoid is a small, laterally compressed median cartilaginous bone, forming floor of the frontal regions of skull and found anterior to basi-sphenoid. (c) **Orbitosphenoids** are found on the sides of the pre-sphenoid. They are partially fused and leave a central area, called optic foramen, intervened by inter-orbital foramen. They articulate with palatines anteriorly, with frontals dorsally, and with squamosals and alisphenoids posteriorly. They also form lateral walls of orbits and cranium.
7. **Frontals**—(a) They are two in number forming the roof and sides of frontal cranium. They unite together in mid-dorsal axis and with parietals posteriorly. (b) Externally each frontal contains supra-orbital process and ventrally articulates with orbitosphenoid.
8. **Nasals**—(a) They are narrow membrane bones forming roof of the olfactory chambers. (b) The anterior ends form upper boundaries of external nostrils and externally each nasal articulates with pre-maxilla.

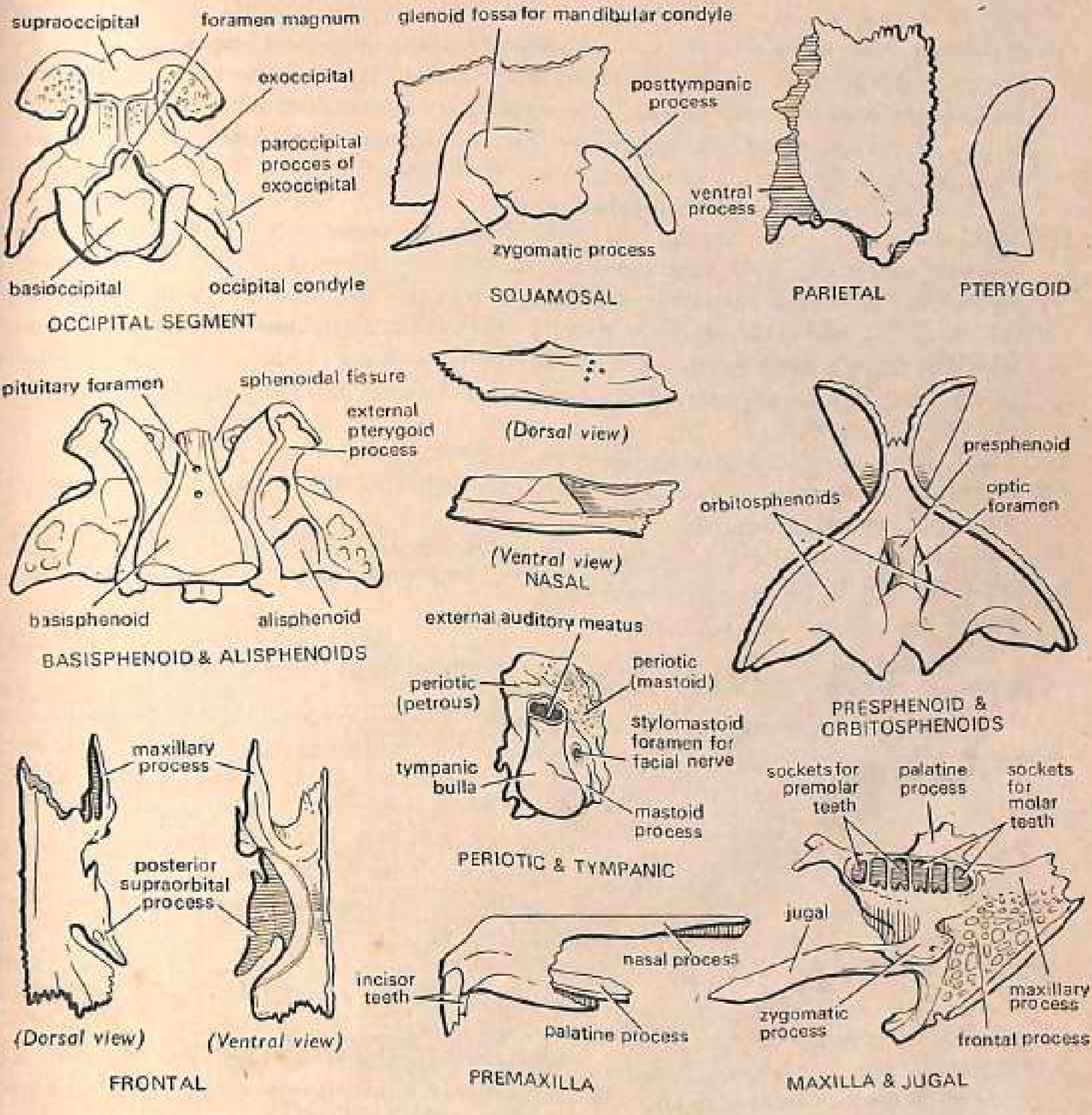


Fig. 6·7. Disarticulated skull bones of Rabbit.

9. **Turbinals**—The olfactory chambers contain irregularly-shaped compound bones consisting of ethmo-turbinal, maxillo-turbinal and naso-turbinal, which increase sensory area.
10. **Vomers**—(a) They are blade-like and slender bones, situated ventrally to olfactory capsules. (b) They are fused and attached to nasal septum.
11. **Peri-otic and tympanic bulla**—(a) It is an irregularly shaped cartilaginous bone of auditory capsule and is composed of three (pro, epi and opisthotic) ossifications. It is loosely fitted between squamosal and occipital ring. (b) The peri-otic is differentiated into inner strong petrous portion, enclosing membranous labyrinth and outer porous mastoid

portion produced into mastoid process. (c) The tympanic bulla is a flask-shaped membrane bone, containing ear ossicles namely malleus, incus and stapes.

12. **Pre-maxilla**—(a) Each pre-maxilla forms anteriormost part of upper jaw. It is elongated and united medially with other. At its tip, it contains two incisors meant for food biting. (b) Pre-maxilla also gives two processes posteriorly, namely dorsal process, which extends backwards up to frontal and ventral nasal process, which divides anterior palatine foramen into two lateral halves.
13. **Maxilla**—(a) A pair of irregular maxillae constitutes major part of upper jaw, sides of face and orbits. (b) Ventrally each maxilla contains six sockets for molar and premolar teeth and anteriorly a maxillary process which joints with pre-maxilla. (c) From the mid-plane of each maxilla arises horizontal **palatal process**, which meets its fellow process forming hard palate. Externally, a strong zygomatic process originates which runs behind to meet jugal forming **zygomatic arch**. The latter forms below the boundary of the orbit.
14. **Jugal**—It is a laterally compressed bone forming major part of the zygomatic arch.
15. **Pterygoid**—It is a small and scale-like bone, attached vertically to the junction of palatine, alisphenoid and basisphenoid.
16. **Palatine**—(a) It is an irregularly-shaped bone on the mid-ventral region of skull. (b) Anteriorly it forms part of hard palate and posteriorly it meets alisphenoid and pterygoid.

DISARTICULATED SKULL BONES OF VARANUS

The disarticulated skull bones of Varanus include occipital region, basi-sphenoid parietals, frontals, pre-frontal, lacrymal, supra-orbital, post-frontal, squamosal, quadrate, nasals, vomer, pre-maxilla, maxilla, jugal, transverse, septo-maxillary, palatine and pterygoid. The lower jaw includes articular, angular, supra-angular, coronoid, splenial and dentary.

1. **Occipital region**—(a) It is posteriormost region of skull enclosing the large **foramen magnum** and composed of supra-occipital, ex-occipitals and basi-occipital. (b) Supra-occipital is situated on the roof of cranium articulating with parietals and pro-otics. (c) Basi-occipital forms floor of the cranium, contains a rounded occipital condyle and articulating with basi-sphenoid, ex-occipitals and pro-otics. (d) Ex-occipitals form wall of cranium and articulate with supra-temporal, squamosal, parietal and quadrate. They are perforated by foramen for X and XII cranial nerves.
2. **Basisphenoid**—(a) It is a broad, flat and nearly rectangular bone, found on the floor of cranium in front of basi-occipital. (b) Anteriorly, it contains a pair of basi-pterygoid processes, which articulate with pterygoids of respective sides. Between basi-pterygoids processes is a reduced knob-like process, which corresponds with parasphenoid of frog. Posteriorly, it articulates with basi-occipital and is free laterally.
3. **Parietals**—The roof of cranial cavity in parietal region is formed by two completely fused parietals, which articulate with quadrate, squamosals, ex-occipitals, post-orbitals, pro-otic, supra-occipital, ex-occipital and epipterygoid.
4. **Frontal**—(a) The roof of frontal cranium is formed by a pair of frontals, which are separated by suture. (b) Due to the absence of sphenoid, the lateral side of frontal is free, while anteriorly it articulates with nasal, antero-laterally with pre-frontal, posteriorly with post-orbital, behind with parietal and beneath with para-sphenoid.

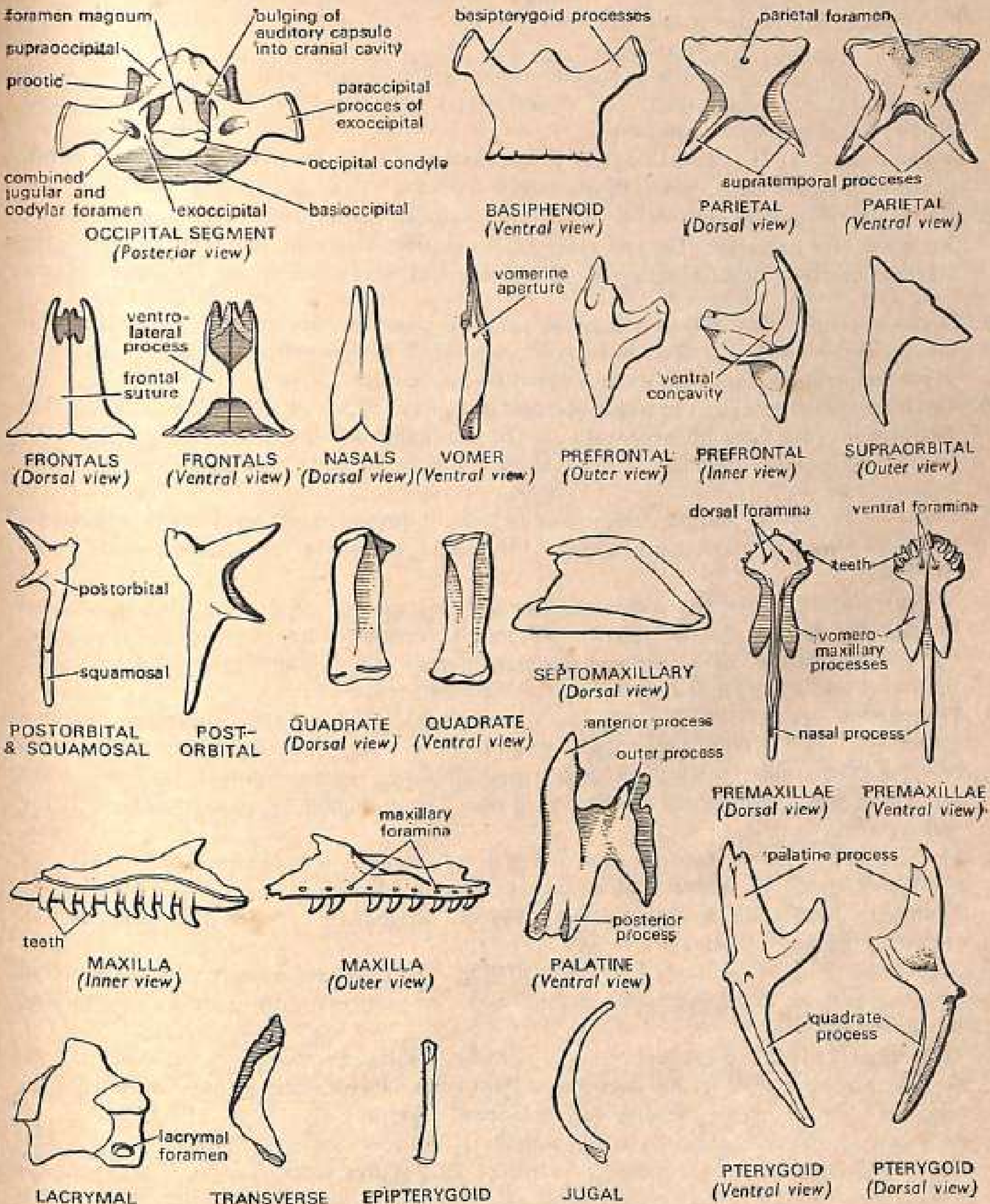


Fig. 6-8. Disarticulated skull bones of *Varanus*.

5. **Pre-frontal**—(a) It is a small and triangular bone found between frontal and maxilla. (b) Ventrally it contains a cup-like concavity and it articulates with supra-orbital and lacrymal.
6. **Lacrymal**—(a) It is a small bone found within margin of orbit and containing a small opening for the lacrymal duct. (b) It articulates with maxilla in front, with jugal behind and with pre-frontal above.
7. **Supra-orbital**—(a) It is a small anchor-shaped bone found at anterior portion of orbit. (b) Its broad base articulates with pre-frontal.
8. **Post-orbital** or **post-frontal**—(a) It forms postero-dorsal boundary of orbit behind frontal. (b) It has four processes. The two inner processes articulate with parietals and frontals. The long posterior process articulates with squamosal, while fourth short process remains free.
9. **Squamosal**—(a) It is a rod-shaped bone, forming posterior portion of supra-temporal arcade. (b) Anteriorly, it articulates with post-orbital while posteriorly with quadrate, supra-temporal, parietal, and para-occipital of ex-occipital.
10. **Quadrate**—(a) It is a stout rod-shaped bone, obliquely attached to postero-lateral side of cranium and it helps in suspensorium. (b) The upper end articulates with squamosal, supra-temporal, parietal and ex-occipital, while the lower end articulates with articular bone of lower jaw.
11. **Nasal**—(a) A pair of nasal bones are fused medianly forming roof of olfactory chambers. (b) Its anterior narrow part articulates with nasal process of pre-maxilla and septo-maxillary.
12. **Vomers**—(a) There are two vomers forming anterior roof of mouth and inner margins of posterior nares. Each vomer is perforated centrally by a vomerine aperture. (b) Vomers are fused anteriorly and separated posteriorly. (c) Anteriorly, they articulate with pre-maxillae and maxillae while posteriorly with palatines.
13. **Pre-maxillae**—(a) The two pre-maxillae are united and fused together, found at anterior extremity. (b) Dorsally it contains a pair of pre-maxillary foramina, ventrally it has 6–8 small teeth and posteriorly it gives three processes, namely **dorsal process**, which articulates with fused nasals, and two wing-like vomero-maxillary processes articulating with vomers.
14. **Maxilla**—(a) A maxilla forms anterior half of upper jaw on either side. (b) It contains 8–10 small, conical and curved, pleurodont teeth and several small maxillary foramina. (c) Maxilla articulates with palatine, pre-maxilla, pre-frontal, supra-orbital, lacrymal, jugal and transverse.
15. **Jugal**—(a) It is a slender bone constituting ventrally outer boundary of orbit. (b) Anteriorly, it articulates with maxilla and lacrymal, inwardly with transverse and free posteriorly.
16. **Transverse**—It is found internal to jugal extending backwards to form floor of orbit.
17. **Septo-maxillary**—(a) It is an irregularly-shaped bone above vomers in nasal region. (b) It articulates with maxilla anteriorly and with nasal posteriorly.
18. **Palatine**—(a) Each palatine is a small, irregularly flattened bone, forming roof of buccal cavity and posterior boundary of inner nare. (b) It has three processes, the anterior process articulates with vomer, posterior with pterygoid and outer with maxilla and transverse.
19. **Pterygoid**—(a) A pair of pterygoid bones also forms roof of mouth. They are of irregular shape containing three processes; anterior process articulates with palatine and transverse

and posteriorly with basi-pterygoid and quadrate. (b) Another slender epipterygoid bone extends between pterygoid and pro-otic.

DISARTICULATED SKULL BONES OF FOWL

The disarticulated skull bones of fowl consist of occipital segment, pre-maxilla, maxilla, jugal, quadrato-jugal, quadrate, nasal, lacrymal, pterygoid, palatine in upper jaw and dentary, etc. in lower jaw.

1. **Occipital segment**—(a) It is the posteriormost region of skull, containing a large foramen magnum and is composed of basi-occipital, ex-occipitals and supra-occipital. (b) Beneath foramen magnum is a single occipital condyle.
2. **Pre-maxillae**—(a) Two pre-maxillaries are completely fused together forming anteriormost region of upper jaw and entire upper beak. (b) Each pre-maxilla contains three processes namely **nasal** process, which ascends to join with frontal forming boundary of external nare, **maxillary** process, which extends backwards and outwards to join with maxilla and **palatine** process, joining with palatine to form palate.
3. **Maxilla**—(a) It is a rod-shaped bone of anterior upper jaw. (a) Anteriorly, it articulates with pre-maxilla and nasal and is expanded into laminated spongy horizontal maxillo-palatine process which articulates with palatine ventrally. (c) Posteriorly, the zygomatic process of maxilla constitutes anterior part of sub-orbital bar.
4. **Jugal**—It is a rod-shaped bone forming middle region of sub-orbital bar and is found dorsal to maxilla and quadrato-jugal.

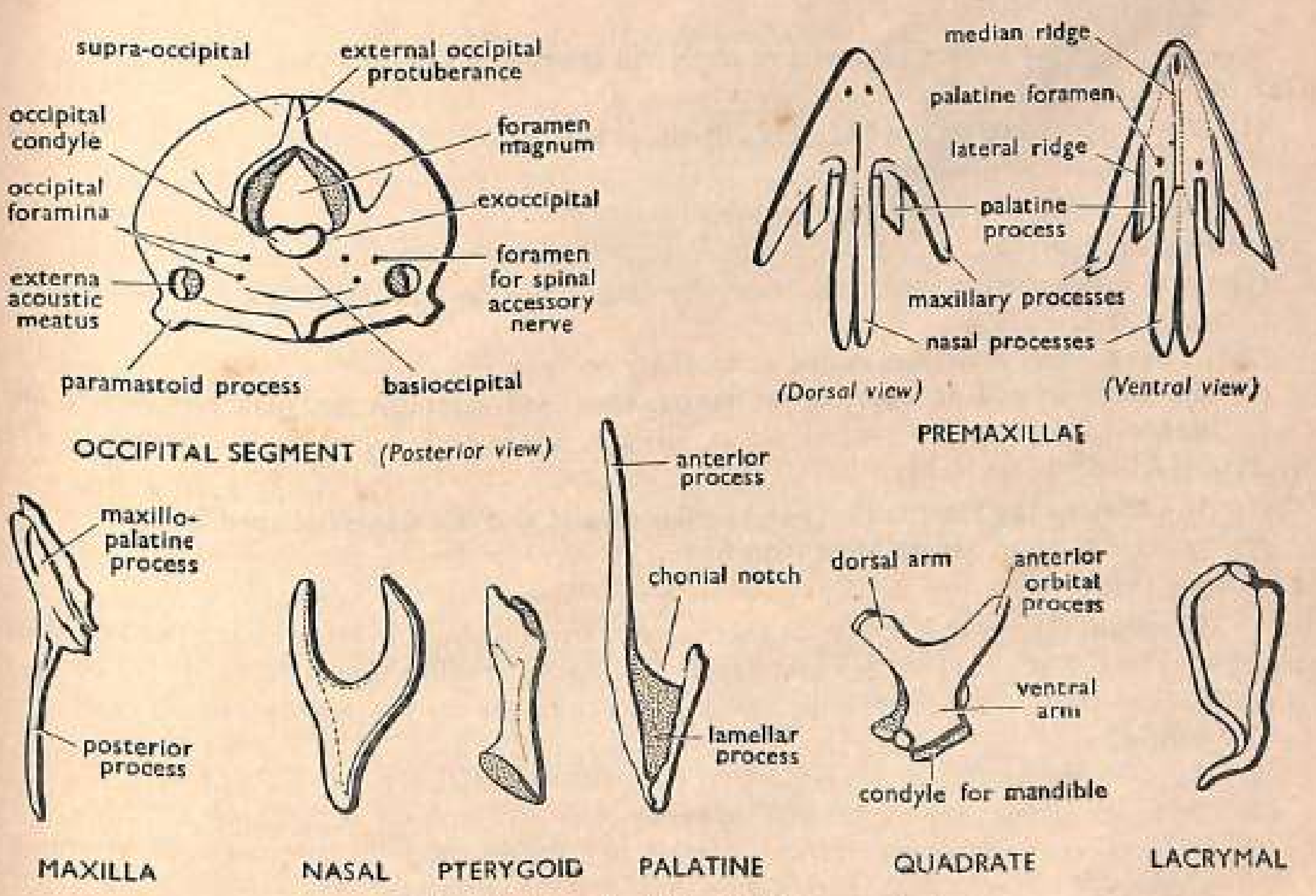


Fig. 6-9. Disarticulated skull bones of Fowl.

5. **Quadrato-jugal**—(a) It forms posteriormost part of sub-orbital bar and is thickened distally to articulate with quadrate.
6. **Quadrate**—(a) It is a tough triradiate bone, situated in front of tympanic cavity and takes part in suspensorium. (b) It has three arms—the anterior arm extends above the pterygoid and terminates freely, the dorsal arm is movable and articulates with squamosal, and the ventral arm gives rise to condyle which articulates with mandible.
7. **Nasal**—(a) The nasals form sides and roof of olfactory chambers and are separated by nasal processes of pre-maxilla. (b) Each nasal is a thin triangular plate-like bone having three processes—the two anterior processes form posterior boundary of external nare and join pre-maxillary processes, the posterior process articulates with frontal and lacrymal.
8. **Lacrymal**—(a) A pair of lacrymals forms anterior boundary of orbits. (b) It contains a curved process and a characteristic foramen.
9. **Pterygoid**—(a) A pair of pterygoids forms posterior boundary of mouth cavity. (b) Each pterygoid articulates with inner surface of ventral arm of quadrate and in front with palatine and para-sphenoid rostrum of its side.
10. **Palatine**—(a) It is a slender and rod-shaped bone forming inner arcade of upper jaw. (b) Anteriorly, palatine joins with maxillary and pre-maxillary processes and it movably articulates with pterygoid. The posterior end is broadened to articulate with **para-sphenoid rostrum**.

LOWER JAW OR MANDIBLE

FROG

The lower jaw of frog is devoid of teeth and consists of the following bones :

(a) Mento-Meckelian

(1) The anterior extremity of Meckel's cartilage becomes ossified forming a small cartilage bone called Mento-Meckelian.

(2) It is found at the anterior symphysis of mandibles.

(b) Angulo-splenial

(1) It is a long, curved lower jaw bone, forming major part of posterior region of each mandible.

(2) It has a small projection called as coronary process.

(3) Its anterior end is pointed, while posterior end contains an articular surface for quadrate cartilage.

(c) Dentary

(1) It is closely applied anteriorly to angulo-splenial and is a dagger-shaped bone.

(2) It extends up to Mento-Meckelian bone.

RABBIT

In rabbit, the lower jaw of each side is made up of a single dentary bone. The two dentaries are joined together at mandibular symphysis. Each mandible shows the following parts—

(1) Postero-lateral surface contains a large meseteric fossa for the attachment of masseter muscle.

(2) Condyle and angle are separated by a deep notch posteriorly.

(3) Teeth are incisor, pre-molars and molars.

(4) Dentary contains several processes such as condyle, angular process and coronoid process.

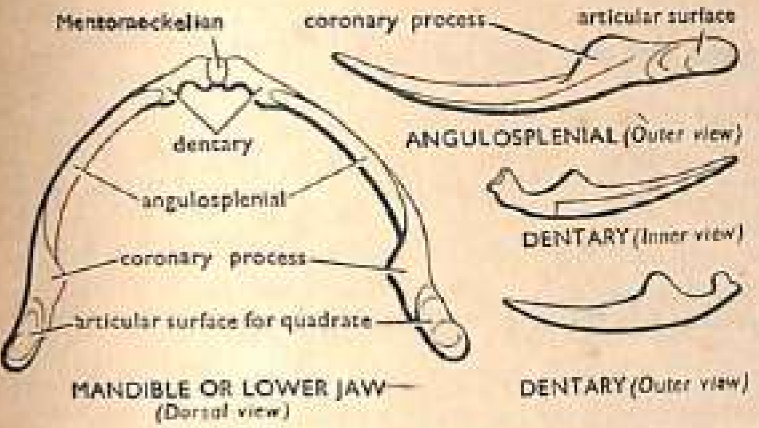


Fig. 6-10. Mandible of Frog.

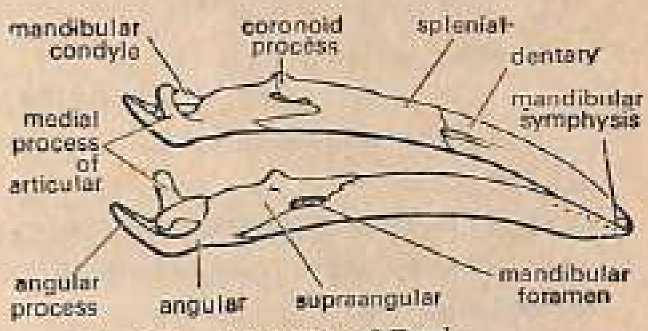


Fig. 6-11. Mandible of Fowl.

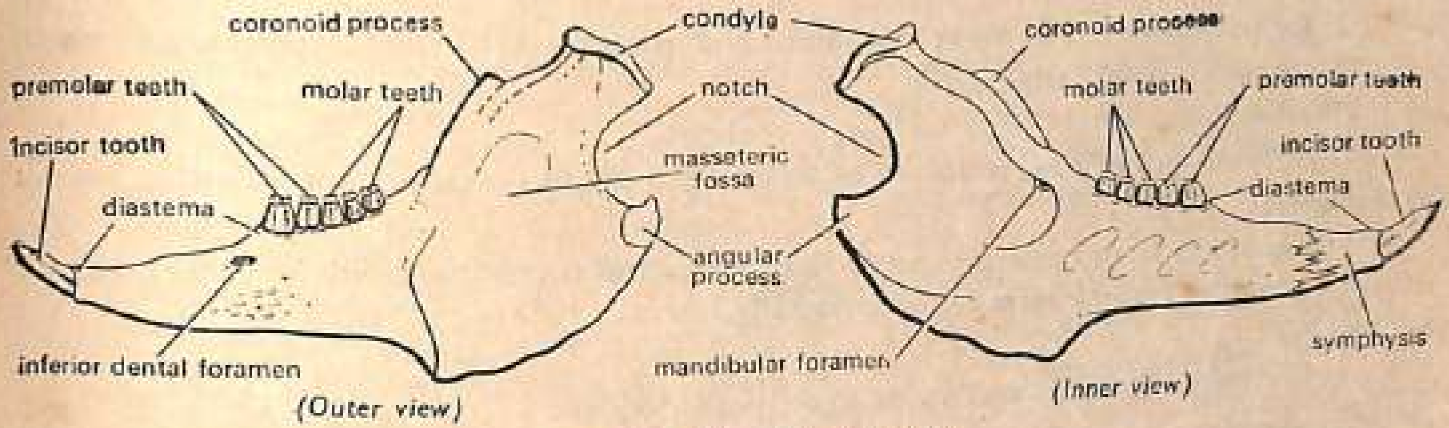


Fig. 6-12. Mandible of Rabbit.

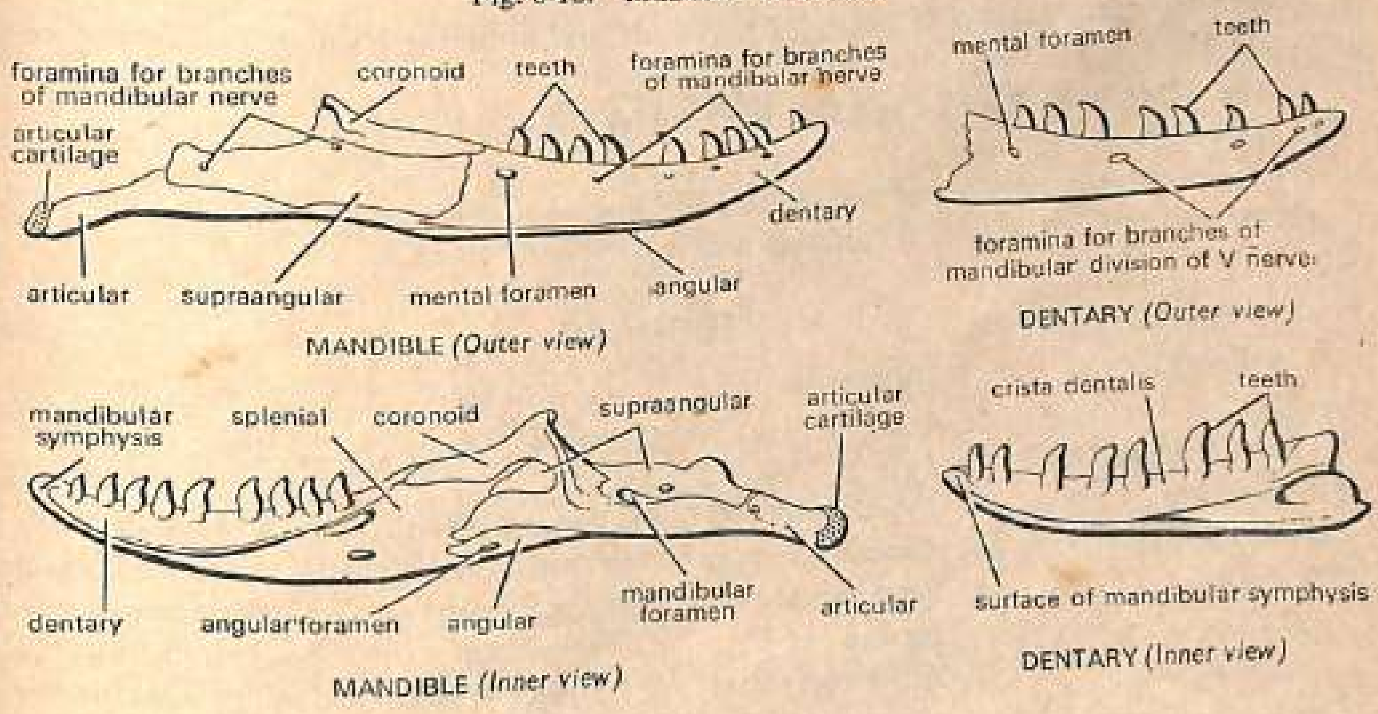


Fig. 6-13. Mandible of *Varanus*.

VARANUS

The lower jaw or mandible comprises of the following parts :

(a) Articular

(1) It is the posteriormost bone of the lower jaw ramus, articulating with quadrate dorsally.

(2) It extends behind angular process which terminates into articular cartilage.

(b) Angular

(1) It is a small splint-like bone, found between dentary and articular.
(2) It is perforated by angular foramen.

(c) Supra-angular

It is an elongated, nearly rectangular bone, found in the middle of each ramus and contains a pair of mandibular foramina.

(d) Coronoid

It is a small process constituting dorsal side of middle ramus and gives rise to a backwardly-directed coronoid process.

(e) Splenial

It is a membranous bone found in a groove on the inner side of dentary.

(f) Dentary

It forms major part of lower jaw ramus and contains 8–10 small, conical, pleurodont teeth along dorsal edge.

FOWL

The lower jaw of fowl is devoid of teeth. Each ramus is made of the following bones :

(a) Articular

(1) It expands from posterior end of each ramus and is continued with Meckel's cartilage.
(2) It contains mandibular condyle dorsally.

(b) Angular

It lies below articular and forms lower border of jaw.

(c) Supra-angular

It forms upper margin of posterior mandible and contains a small coronoid process.

(d) Splenial

It is a thin bone found along the inner surface of middle mandible.

(e) Dentary

(1) It forms anterior half of mandible and joins with fellow dentary at symphysis.
(2) It is devoid of teeth and contains a mandibular foramen.

VERTEBRATE

Frog	Varanus	Fowl	Rabbit
1. Atlas	1. Atlas	1. Atlas	1. Atlas
2. Typical, 2nd to 7th	2. Axis	2. Axis	2. Axis
3. 8th vertebra	3. Typical cervical	3. Typical cervical	3. Typical cervical
4. 9th vertebra	4. Thoraco-lumber	4. Fused thoracic	4. Anterior thoracic
5. Urostyle	5. First sacral	5. Free thoracic	5. Posterior thoracic
	6. Second sacral	6. Synsacrum (Thoracic, lumber sacral, anterior caudal)	6. Anterior lumber
	7. Anterior caudal	7. Free caudal	7. Posterior lumber
		8. Pygostyle	8. Sacrum
			9. Caudal

VERTEBRAE OF FROG

1. **Atlas**—(a) It is a ring-shaped bone with reduced centrum on one face only. (b) Anteriorly centrum contains two large concave facets for articulation with occipital condyles. (c) Pro-zygapophyses absent, neural spine reduced and post-zygapophyses present.
2. **Typical 7th vertebra**—It is a typical vertebra. It is also nearly ring-shaped bone, having a large **neural canal** for spinal cord. (b) **Centrum procoelous** with anterior concave face and posterior convex face. (c) **Neural spine** is blunt and transverse processes are long and tapering on either side of centrum. (d) **Pre-zygapophyses** are inwardly and upwardly directed, while **post-zygapophyses** are downwardly and outwardly directed. (e) The **second** and **fourth vertebrae** are like typical vertebra except that in former neural spine is short and transverse processes broad, while in latter transverse processes are long and broad distally.

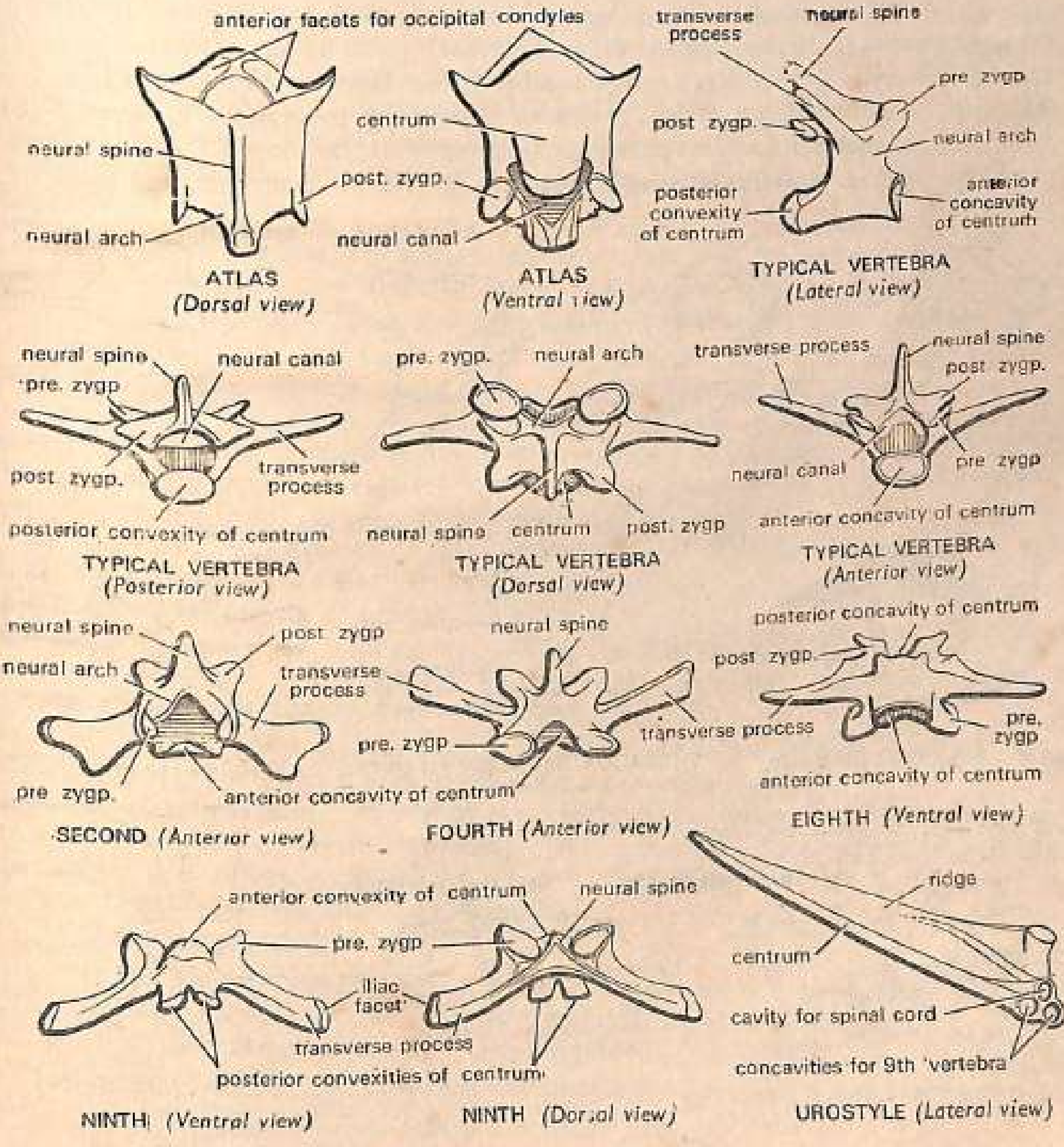


Fig. 6-14. Vertebrae of Frog.

3. **Eighth vertebra**—(a) The centrum is **amphicoelous** or biconcave. The anterior part of centrum receives posterior convexity of seventh vertebra and posterior part receives anterior convexity of ninth vertebra. Other parts of vertebra are transverse processes, pre- and post-zygapophyses.
4. **Ninth or sacral vertebra**—(a) It has **biconvex centrum.** Single anterior convexity fits into posterior concavity of eighth vertebra, while two posterior convexities fit into anterior concavities of urostyle. (b) The transverse processes are long and cylindrical, obliquely and backwardly directed to articulate with ilia bones of pelvic girdle.
5. **Urostyle**—(a) It is last part of vertebral column and quite elongated. (b) Centrum is rod-shaped which contains two concavities anteriorly for articulation with the ninth vertebra.

VERTEBRAE OF VARANUS

1. **Atlas**—It is also a ring-shaped bone, composed of three pieces, two dorso-lateral and one ventral. The centrum and transverse processes are absent. (b) During living condition the neural canal is divided into dorsal and ventral parts by a ligament. (c) It contains anterior concavity for occipital condyle and posterior facet for odontoid process.
2. **Axis**—(a) It is the second cervical vertebra. Transverse processes are absent. (b) Pre-zygapophyses reduced, while post-zygapophyses well developed. Neural spine large crest like. (c) Axis contains a spine-like process, the odontoid process, and hypapophysis.

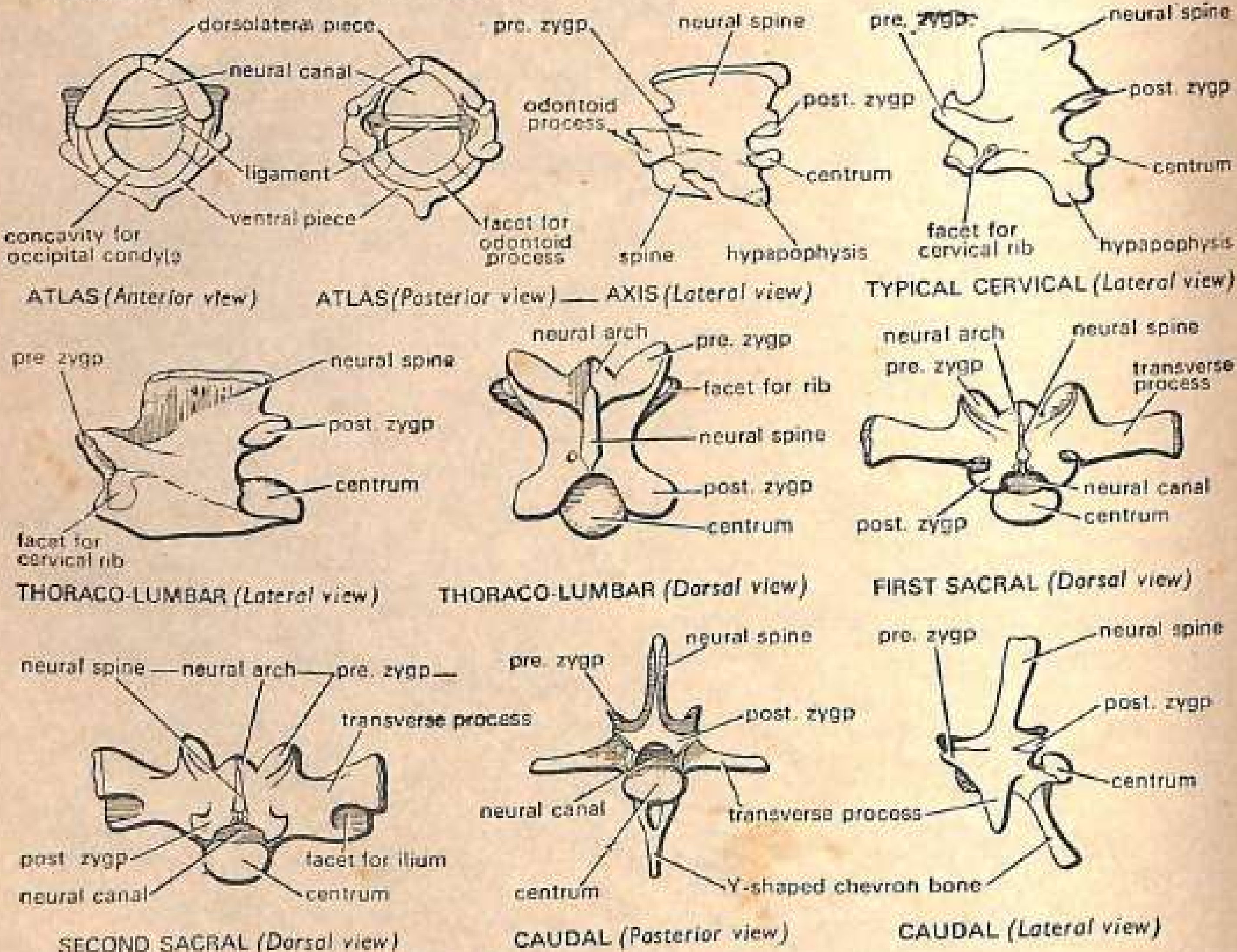


Fig. 6-15. Vertebrae of *Varanus*.

3. **Typical cervical**—(a) Centrum elongated and strongly **procoelous**. It contains a ventral backwardly-directed hypapophysis. (b) Neural spine is crest-like. Neural arch contains a pair of anterior upwardly-directed pre-zygapophyses and a pair of posterior backwardly-directed post-zygapophyses. Behind third vertebra, each cervical contains a pair of lateral facets for articulation of ribs.
4. **Thoraco-lumbar**—(a) They are larger than cervical with strongly procoelous centrum and well developed pre- and post-zygapophyses. (b) Hypapophysis absent and at the junction of neural arch and centrum, a distinct capitular facet is present to articulate with rib in each vertebra.
5. **First sacral**—(a) It supports pelvic girdle. The centrum is procoelous, pre- and post-zygapophyses well developed. (b) Neural spine slightly crest-like. Transverse processes greatly expanded and notched to articulate with ilia.
6. **Second sacral**—(a) It resembles first sacral in having procoelous centrum, lower crest-like neural spine and well-developed pre- and post-zygapophyses. (b) It differs from first sacral in the absence of a notch in transverse processes.
7. **Anterior caudal**—(a) It is like sacral superficially, but it contains long centrum, slender, transverse and neural spine processes and fairly developed zygapophyses. (b) Specific feature of the vertebra is the presence of a Y–shaped **chevron bone.**

VERTEBRAE OF FOWL

1. **Atlas**—(a) Atlas or first cervical is ring-shaped, roughly triangular bone, composed of two dorso-lateral and one ventral pieces. The ventral part contains a concavity for occipital condyle and a notch for odontoid process. (b) Centrum, neural spine, ribs, transverse processes and pre-zygapophyses are absent.
2. **Axis** or **epistropheus**—(a) It is also called as second cervical which is without transverse processes, ribs and vertebral canals. (b) Neural spine, pre-zygapophyses and post-zygapophyses present. (c) Centrum heterocoelous and produced into an anterior odontoid process.
3. **Typical cervical**—14 in number. (a) Centrum heterocoelous. The neural arch short and neural spine rudimentary. (b) Transverse processes short and irregular and fused with thin, backwardly-directed reduced cervical ribs. (c) Pre-zygapophyses flat while post-zygapophyses project downwards and outwards.
4. **Fused thoracic**—(a) 7 in number and second to fifth vertebrae are fused. (b) Due to complete fusion, the neural spines, transverse processes and hypapophyses look like plates which are perforated by intervertebral gaps.
5. **Free thoracic**—(a) First and sixth are free vertebrae. (b) Each vertebra has heterocoelous centrum, hypapophysis and it also carries double-headed thoracic ribs.
6. **Synsacrum**—(a) Synsacrum is formed by last thoracic, 6 lumbar, 2 sacral and 7 caudal vertebrae. (b) Thoracic vertebra contains a pair of thoracic ribs. (c) Lumbar vertebrae are firmly fused together with free transverse processes and without hypapophyses. (d) Sacral vertebrae fuse to form bony plates.

VERTEBRAE OF RABBIT

1. **Atlas**—(a) It is first cervical and signet-ring like. (b) Centrum, zygapophyses absent and neural spine is rudimentary. On the sides are present flattened cervical ribs, the so-called transverse processes. (c) Anteriorly, it contains two facets for occipital condyles and posteriorly, three facets for odontoid process. (d) During living condition, neural canal divided by a ligament.

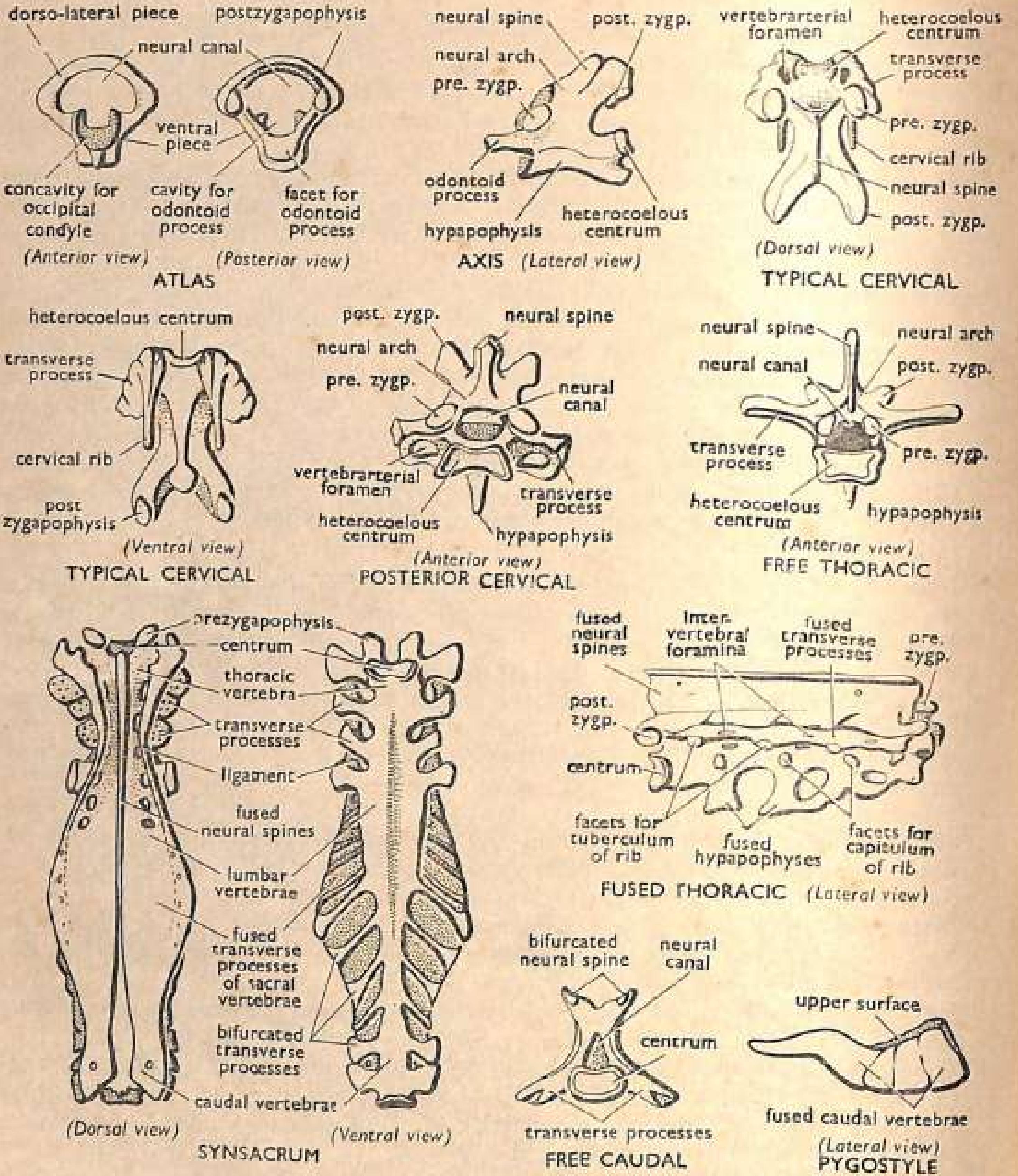


Fig. 6-16. Vertebrae of Fowl.

2. **Axis**—(a) It is second cervical. (b) Neural spine is flattened, antero-posteriorly elongated and ridge like. The cervical ribs or so-called transverse processes are small. (c) Centrum contains peg-like odontoid process and pre-zygapophyses absent.
3. **Typical cervical**—(a) Rest of the cervicals are typical having small neural spine, large neural arch, flattened centrum, pre-zygapophyses and post-zygapophyses. (b) Transverse process bifurcated and perforated by vertebral arterial canal.

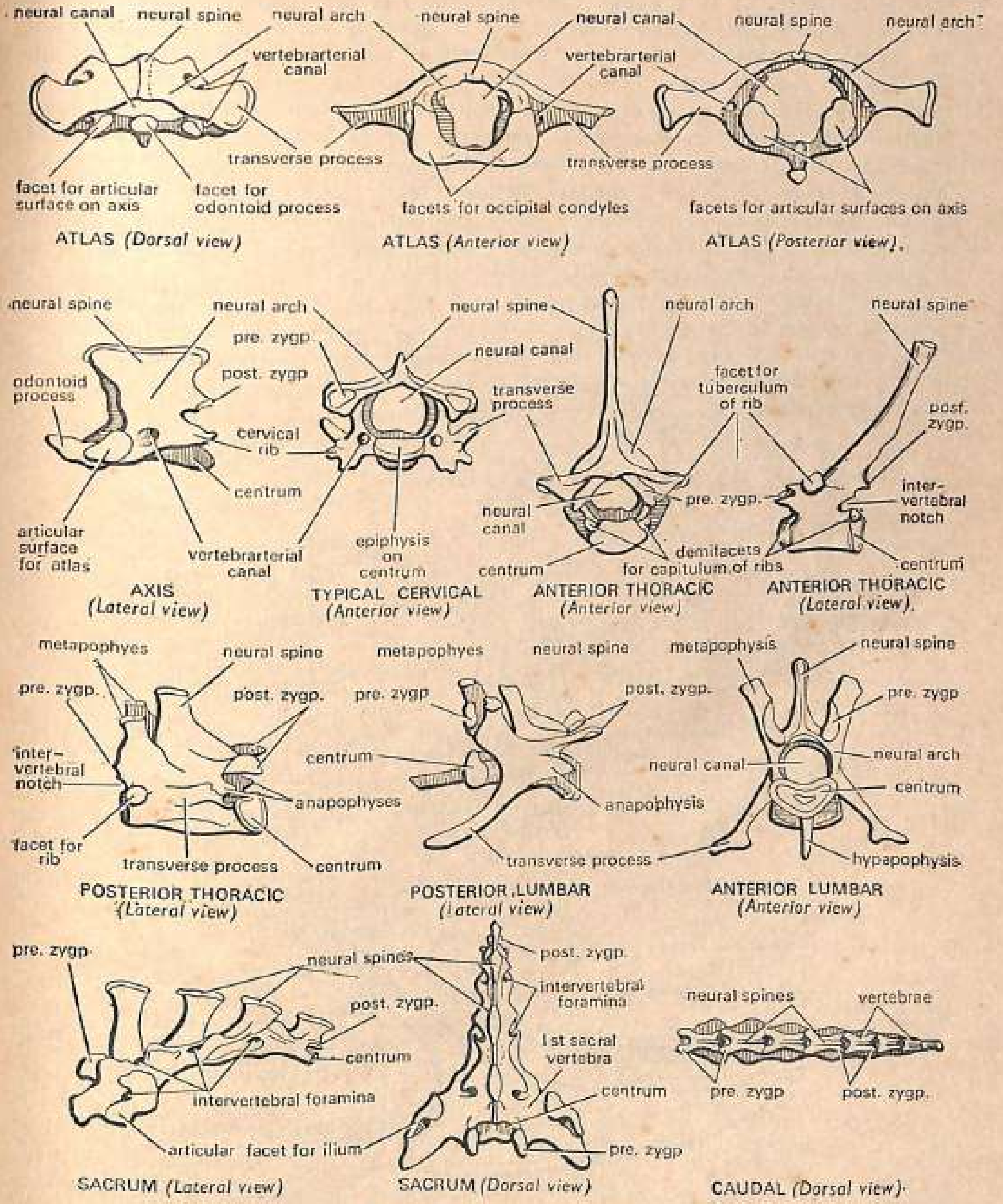


Fig. 6-17. Vertebrae of Rabbit.

4. **Anterior thoracic**—(a) It contains backwardly-oriented neural spine. Neural arch has upwardly-directed pre-zygapophyses and downwardly-directed post-zygapophyses. (b) Transverse processes are short and contain facets for tuberculum of a rib. (c) Centrum is short.
5. **Posterior thoracic**—(a) Last 4 or 5 thoracic vertebrae differ from anterior one in having long centrum, shorter neural spine, distinct zygapophyses and reduced transverse processes. (b) It contains capitular facets, metapophyses and anapophyses.
6. **Anterior lumbar**—(a) Out of 7 lumbars, first two may be called as anterior lumbar. (b) The neural arch of each vertebra on either side contains anteriorly metapophysis, which contains pre-zygapophysis and posteriorly a backwardly-directed process, called as anapophysis below post-zygapophysis.
7. **Posterior lumbar**—(a) 3rd to 7th vertebrae are called as posterior lumbar. (b) They resemble anterior lumbar in all respects except that the hypapophysis is ridge like.
8. **Sacrum**—(a) Sacral vertebrae (4 in number) are fused to form a compact bone supporting pelvis. (b) The neural spines, zygapophyses and intervertebral foramina are peculiar. (c) Metapophyses are reduced and anapophyses are absent.

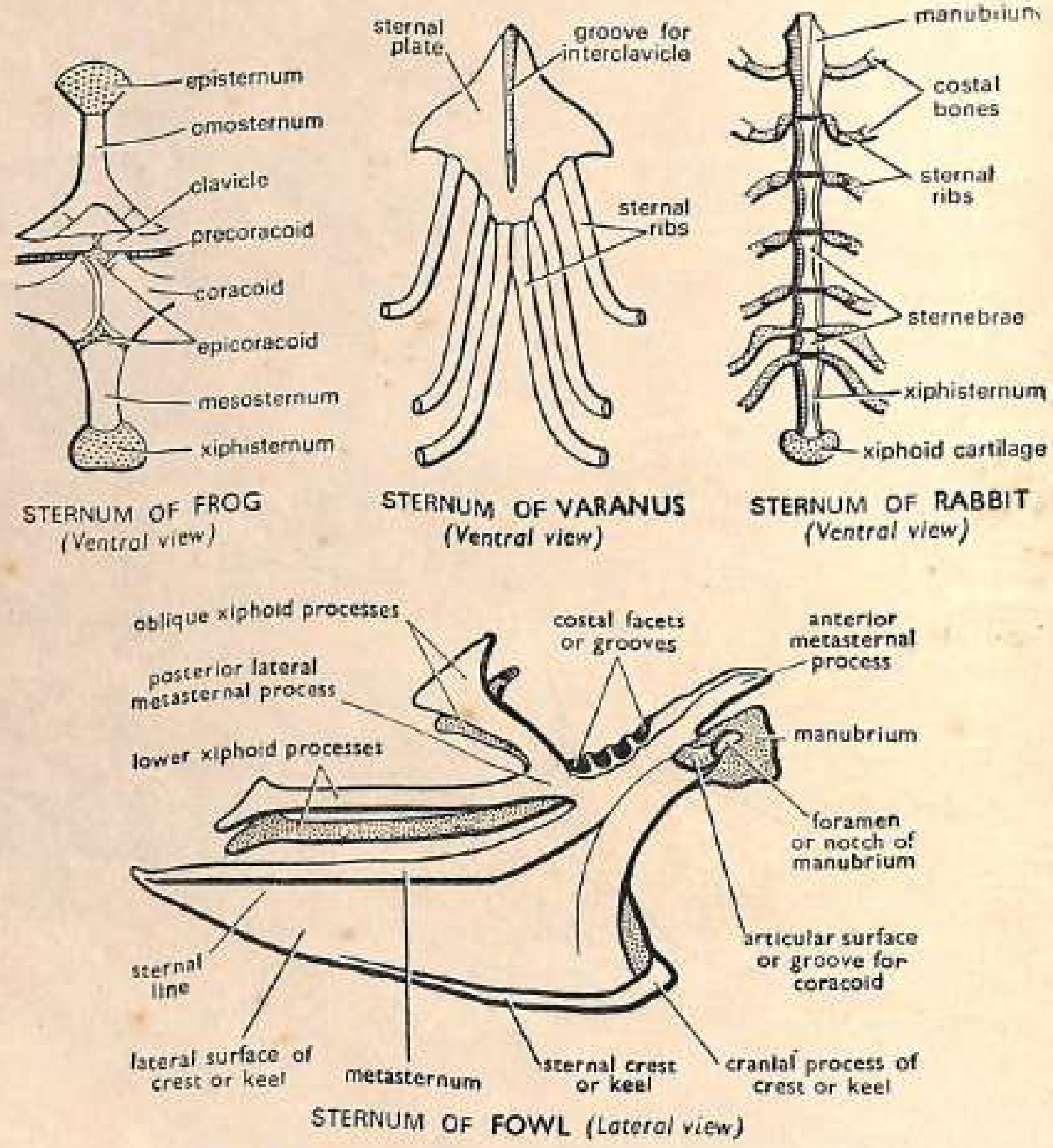


Fig. 6-18. Sternum of Frog, *Varanus*, Fowl and Rabbit.

COMPARISON OF STERNUM

FROG	VARANUS	FOWL	RABBIT
1. Sternum is fused between two halves of pectoral girdle. 2. It is composed of the following four parts, each having a shaft and head: (a) **Episternum**—It is a cartilaginous flat disc, anteriorly situated. (b) **Omosternum**—It connects clavicles. (c) **Mesosternum**—It is a cartilaginous rod projecting behind epicoracoids. (d) **Xiphisternum** — The head of mesosternum is called xiphisternum.	1. Sternum is in the form of a rhomboidal calcified cartilaginous plate. 2. Antero-laterally it articulates with coracoids and epicoracoids of pectoral girdle. 3. Posteriorly it bears three notches for sternal ribs. 4. It is attached with T-shaped interclavicle.	Sternum of fowl is well developed and is called as breast bone. It is boat-shaped and composed of the following structures : (a) **Metasternum**—It is main part, concave dorsally and convex ventrally. (b) **Manubrium** — Ventral surface of metasternum is produced into manubrium. (c) **Keel**—It is formed from the ventral convex surface of metasternum. (d) **Metasternal processes**—Anterior processes are **costal processes** and posterior processes are **metostea** or **xiphoid.** (e) **Costal surfaces**—4 or 5 cup-like depressions for sternal ribs.	1. Sternum is segmented, consisting of 6 bones and embedded in the thoracic wall. 2. First bone is called as **manubrium** and last **xiphisternum** which contains cup-shaped **xiphoid** cartilage.

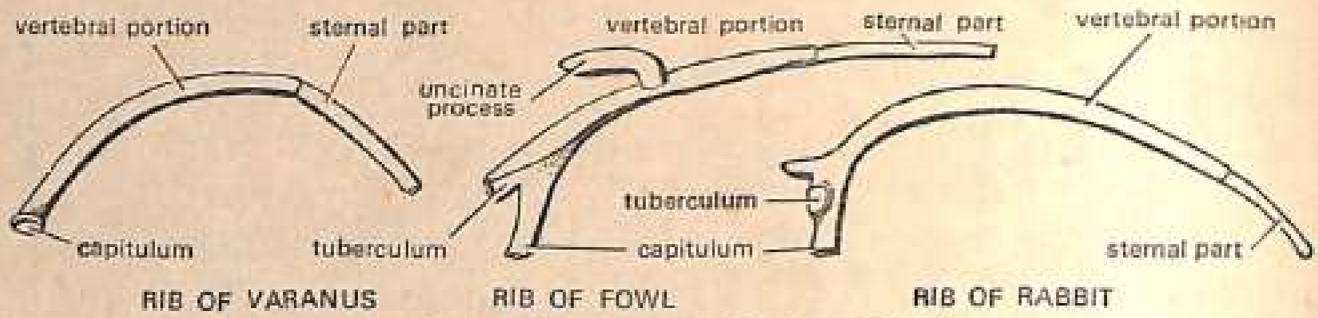


Fig. 6-19. Ribs of *Varanus*, Fowl and Rabbit.

THORACIC RIBS

VARANUS

All the thoracic vertebrae bear one pair of thoracic ribs. They are slender, curved rods of bone and cartilage. Each rib is differentiated into a dorsal bony *vertebral portion* and a ventral cartilaginous *sternal portion*. Ribs are unicephalous or single-headed, that is, the vertebral end bears a single facet, or *capitulum,* which articulates with the centrum of the vertebra. The sternal parts of the anterior three thoracic ribs reach ventrally to join the sternal plate.

FOWL

There are 7 pairs of thoracic ribs in fowl, one pair articulating with each thoracic vertebra. Normally each rib is made of a dorsal *vertebral portion* and a ventral *sternal portion.* The vertebral end is bicephalous, that is, consisting of two heads, a *capitulum* for the centrum and a *tuberculum* for the transverse process of the thoracic vertebra. The vertebral part bears a prominent backwardly-directed *uncinate process*, which overlaps the next rib behind and is characteristic of birds.

RABBIT

The thoracic vertebrae carry each one pair of thoracic ribs. The ribs are slender, curved and each differentiated into a dorsal bony *vertebral portion* and a ventral cartilaginous *sternal portion.* The vertebral end is bicephalous or two-headed, bearing two facets, the *capitulum* and the *tuberculum,* articulating with the centrum and transverse process of the thoracic vertebra.

PECTORAL GIRDLES

FROG

1. Pectoral girdle is found embedded in the body wall in thoracic region. It is composed of two identical halves, which are permanently attached with sternum.
2. Each half is composed of **scapular** and **coracoid** regions.
3. Scapular region consists of **supra-scapula** and **scapula**. Supra-scapula is broad, flat and rectangular bone having free calcified cartilaginous margin. Scapula is also flat and contains a cup-like **glenoid cavity** for humerus.
4. Coracoid region is made up of two bones, namely **clavicle** and **coracoid**, and two cartilages viz.—**epicoracoid** and **pre-coracoid**.
5. Pectoral girdle protects viscera and gives support to limbs.

VARANUS

1. Pectoral girdle of *Varanus* is also made up of two identical halves, firmly attached with T-shaped interclavicle.
2. Each half is composed of **supra-scapula, scapula, coracoid, interclavicle** and **clavicle.**
3. **Supra-scapula**—It is flattened, calcified and cartilaginous plate, articulating ventrally with scapula, while dorsal margin is free and curved.

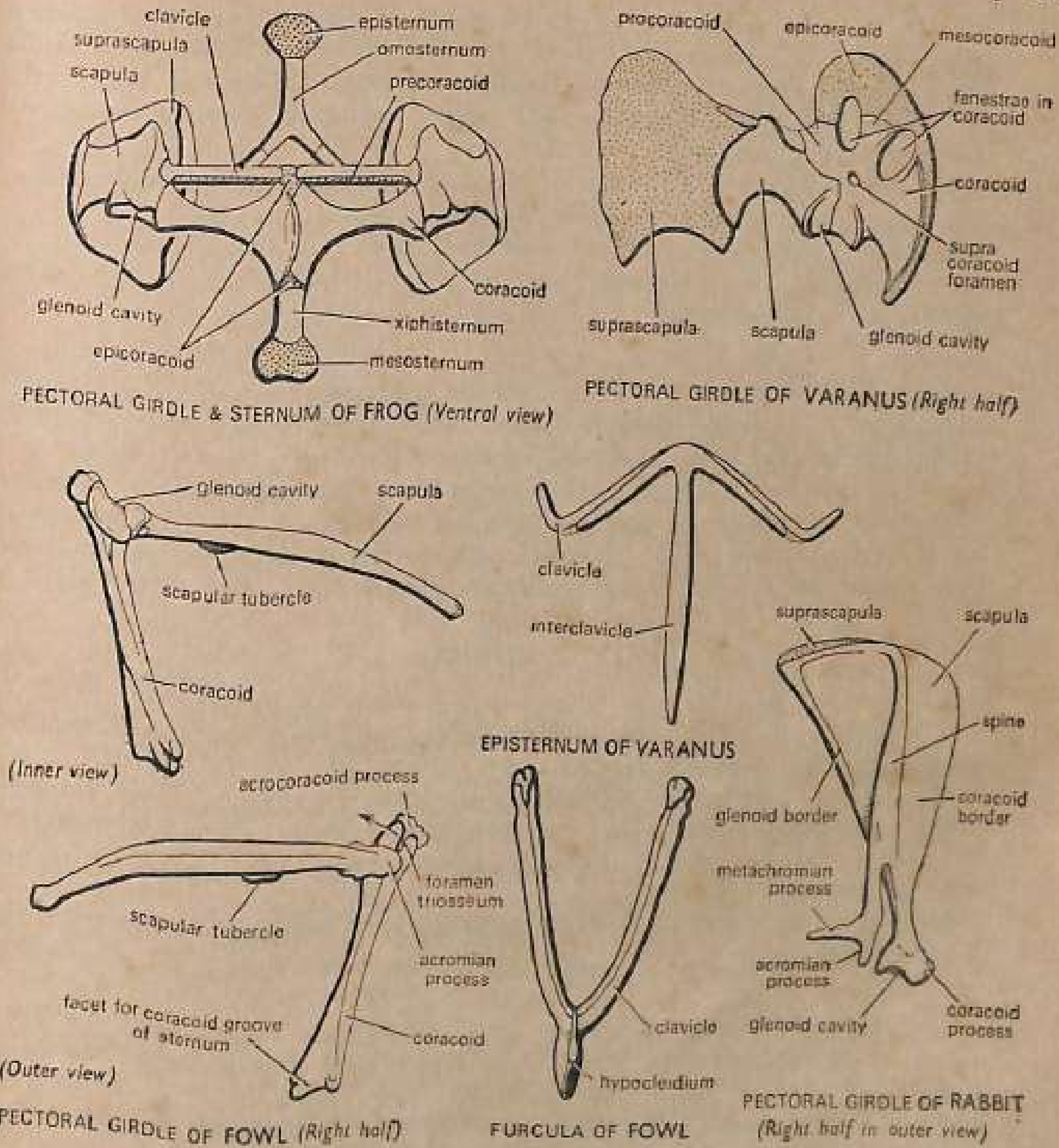


Fig. 6-20. Pectoral girdles of Frog, *Varanus*, Fowl and Rabbit.

4. **Scapula**—It is completely ossified, flattened and unfenestrated plate, articulating with supra-scapula and coracoid.
5. **Coracoid**—It is a flat bone partly ossified and partly cartilaginous. It contains two large fenestrae, which divide ossified region into three parts namely anterior **pre-coracoid**, middle **mesocoracoid** and posterior broad **coracoid proper**. Inner end of coracoid is termed **epicoracoid**.
6. **Interclavicle**— T-shaped investing bone between two halves.
7. **Clavicle**– It is a short and curved dermal bone, articulating with supra-scapula and interclavicle.

FOWL

1. The pectoral girdle is peculiarly inverted L-shaped (⅂) bone and is composed of **coracoid, scapula and clavicle.**

2. **Coracoid**—(a) It is a large, stout and rod-shaped bone. The distal end is produced into hook-like *acrocoracoid process*, while proximal end is flattened to articulate with coracoid groove on the antero-lateral border of sternum. (b) Below acrocoracoid process, the inner surface of coracoid articulates with scapula, while outer surface contains a cup-shaped glenoid cavity for humerus head.
3. **Scapula**—(a) It is a sabre-like bone. (b) Anteriorly it contains a cup-shaped depression, forming part of glenoid cavity and on inner side it has acromian process.
4. **Clavicles**—(a) They fuse to form a V-shaped *furcula* or *merrythought* or *wishbone*. (b) Each clavicle is a rod-shaped bone. (c) Ventrally two clavicles unite to form interclavicle or hypocleidium.

RABBIT

1. Each half of pectoral girdle is made up of **clavicle and scapula-coracoid.**
2. **Clavicle**—(a) It is a slender, rod-shaped, curved and membrane bone. (b) It articulates with manubrium of sternum and acromian process of scapula.
3. **Scapula-coracoid**—(a) It is a triangular replacing bone. The apex contains a concavity called as **glenoid** cavity for humerus head and over glenoid cavity hangs *coracoid process*. (b) A distinct vertical *spine* divides outer surface of scapula and it terminates into *acromian process*, which further gives *metacromian process*.

PELVIC GIRDLES

FROG

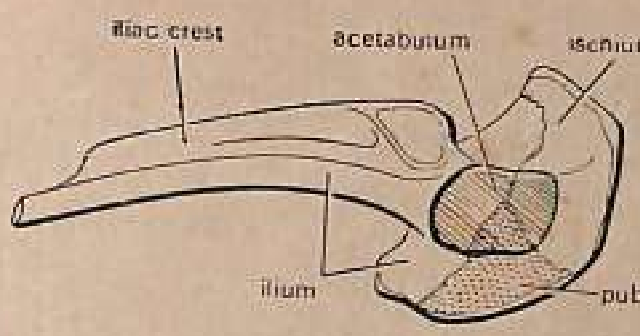
1. The two pelvic girdles form V-shaped structure. Each girdle or *innominatum* is composed of **ilium, ischium, pubis** and **acetabulum.**
2. **Ilium**—(a) It is a long bone meeting with transverse process of ninth vertebra. (b) Dorsally it contains a distinct *iliac crest*. (c) Two ilia meet posteriorly at iliac symphysis.
3. **Pubis**—It is reduced calcified cartilage forming major part of acetabulum. Two pubic cartilages are completely fused.
4. **Ischium**—Two ischia give rise to one-third of disc and completely fuse together at ischiatic symphysis.

VARANUS

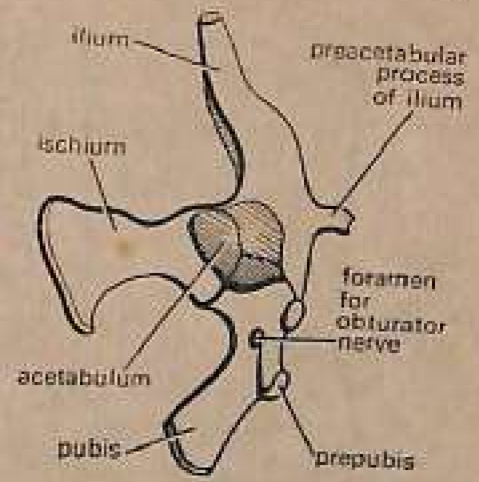
1. (a) It is composed of usual three bones namely illum, pubis and ischium. (b) Three bones are very hard and solid. Externally, at the junction of three bones is a large *acetabulum* for head of femur. (c) Joints distinct.
2. **Ilium**—It is a rod-shaped bone constituting major part of *acetabulum* and articulating with sacral vertebrae. It has a *pre-acetabular process*.
3. **Pubis**—(a) It is a curved bone. (b) The two pubes meet at *pubic symphysis*, which in front contains *epipubis*. Pubis contributes to one-third of *acetabulum* and is perforated by a small foramen for *obturator nerve*.
4. **Ischium**—The two ischia are flat and curved bones meeting at *ischiatic symphysis*. From the ischiatic symphysis, a rod-shaped hypo-ischium extends backwards to support ventral wall of cloaca.

FOWL

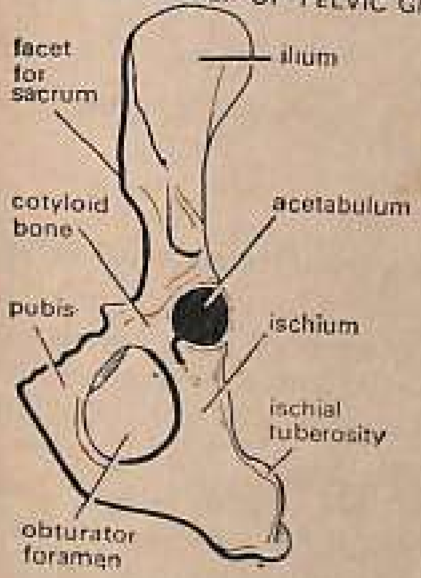
1. Although pelvic girdle of fowl contains usual three parts, namely ilium, ischium and pubis, yet it is noteworthy because of (1) absence of ventral symphysis due to large eggs, (2) firm union with vertebral column, and (3) incomplete ossification of acetabulum.
2. **Ilium**—(a) Ilium is a long lamellar bone differentiated into *pre-acetabular* and post-acetabular parts. (b) Ilium forms dorsal part of the acetabulum.



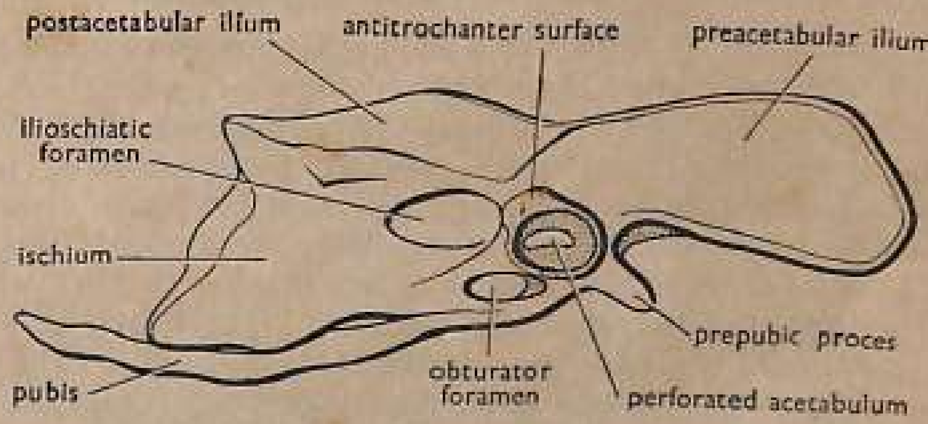
LEFT HALF OF PELVIC GIRDLE OF FROG *(Lateral view)*



PELVIC GIRDLE OF VARANUS
(Left Os innominatum in ventral view)



PELVIC GIRDLE OF RABBIT
(Left half in lateral view)



RIGHT OS INNOMINATUM OF PELVIC GIRDLE OF FOWL *(Outer view)*

Fig. 6-21. Pelvic girdles of Frog, *Varanus*, Rabbit and Fowl.

3. **Ischium**—It extends behind acetabulum and is fused with ilium posteriorly and separated anteriorly by *ilio-ischiatic* foramen.
4. **Pubis**—It is a slender bone forming ventral part of acetabulum. Behind acetabulum pubis is separated from ischium by *obturator foramen.*

RABBIT

1. The two halves of pelvic girdles are united at a *pubic symphysis*. Each half of *innominatum* contains *ilium*, *ischium* and *pubis*. The three bones are fused together forming hip bone. External to each bone is a cup-shaped *acetabulum.*
2. **Ilium** is a blade-like bone and it articulates with sacrum.
3. **Ischium**—It forms postero-dorsal part of innominate bone. The posteriormost part is thickened forming *ischial tuberosity*.
4. **Pubis** is a small bone forming ventro-lateral part of girdle. A small cotyloid bone prevents pubis from reaching up to acetabulum. Pubis is separated from ischium by a large obturator foramen.

FORELIMB BONES

FROG

Humerus, radio-ulna and hand bones constitute bones of forelimb.

1. **Humerus**—(a) It is a short, cylindrical and slightly curved bone of upper arm. The proximal end fits into glenoid cavity of pectoral girdle. It is swollen forming *head*, which is covered by calcified cartilage. (c) Below head is a *deltoid ridge* for muscle

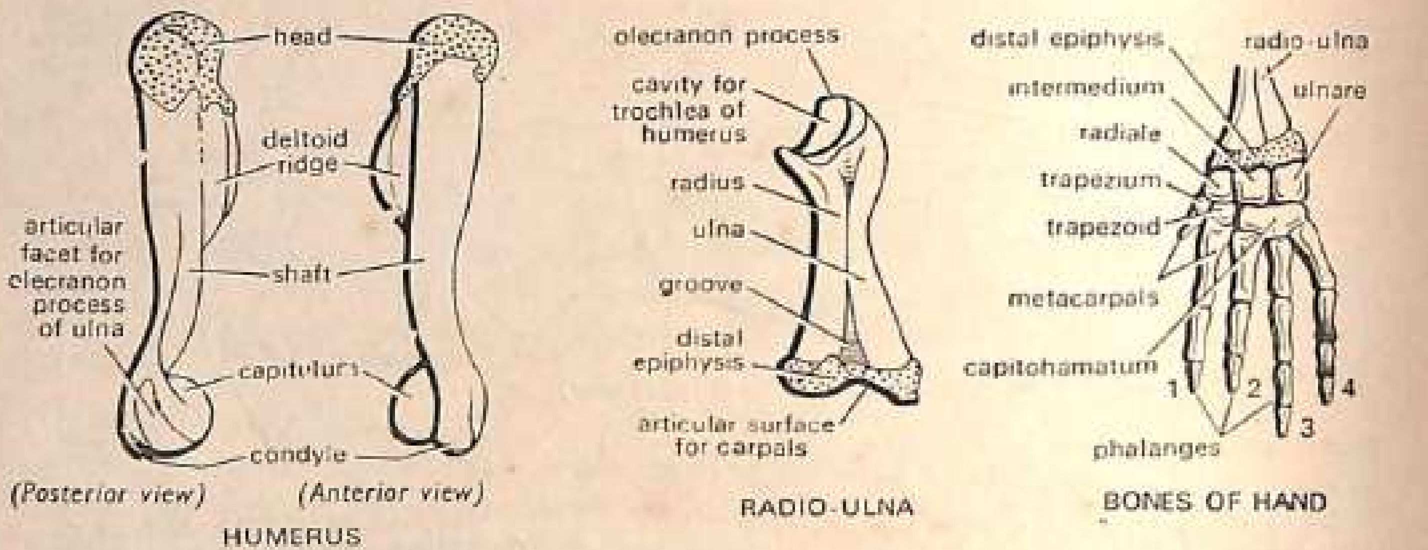


Fig. 6-22. Forelimb bones of Frog.

attachment. (d) The distal end has a prominent *trochlea* or *capitulum* and a *condylar ridge* for articulation with radio-ulna.

2. **Radio-ulna**—(a) It is a compound bone of forearm formed by fusion of radius and ulna bones. (b) At the proximal end it contains a concavity for articulation with *capitulum* of humerus and an *olecranon process.* (c) A groove divides radius and ulna distally; each terminates into a facet to articulate with carpal bones.
3. **Bones of hand**—(a) Wrist bones are called as carpals, which are six in number and arranged in two rows of three each. The bones of proximal row namely radiale, intermedium and ulnare articulate with radio-ulna. The bones of distal row namely trapezium, trapezoid and capitatohamatum articulate with metacarpals. The first metacarpal is rudimentary. First digit is absent, rest are internally supported by short bony rods, known as *phalanges*. First and second digits contain two phalanges each, while third and fourth digits have 3 phalanges each.

VARANUS

Forelimb is constituted by humerus, radius and ulna and bones of forefoot.

1. **Humerus**—(a) It is upper arm single bone with both ends expanded. (b) The proximal end contains *head* which fits into glenoid cavity. The head and a medial process enclose a *bicipital fossa*. (c) Deltoid ridge present. (d) Distal end pulley-like and trochlea contains two articular facets for radius and ulna.
2. **Radius and ulna**—(a) Unlike frog, the forearm radius and ulna are not fused. (b) Radius is slender and made up of a shaft and two epiphyses. The distal end contains a concave articular facet and a pre-axial styloid process. (c) The ulna is stouter. The proximal end contains olecranon process and distal end has a convex articular surface for carpus.

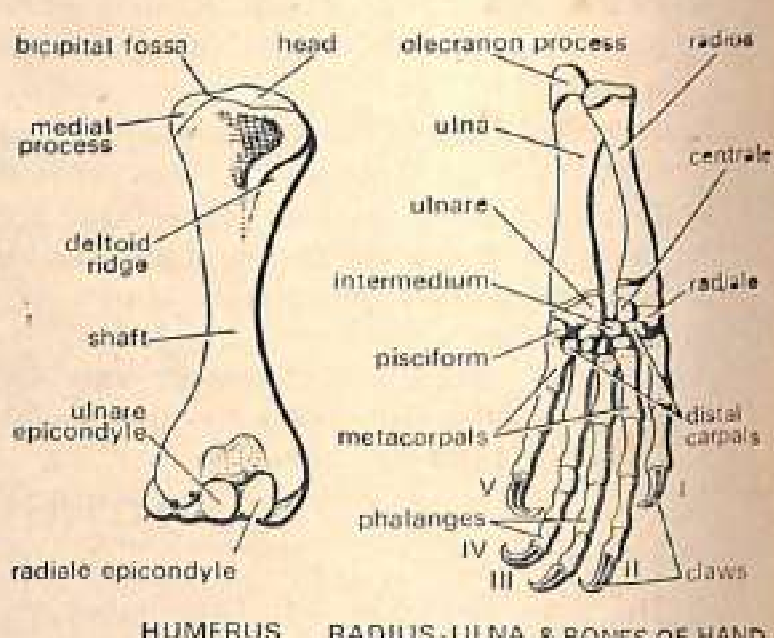


Fig. 6-23. Forelimb bones of *Varanus*.

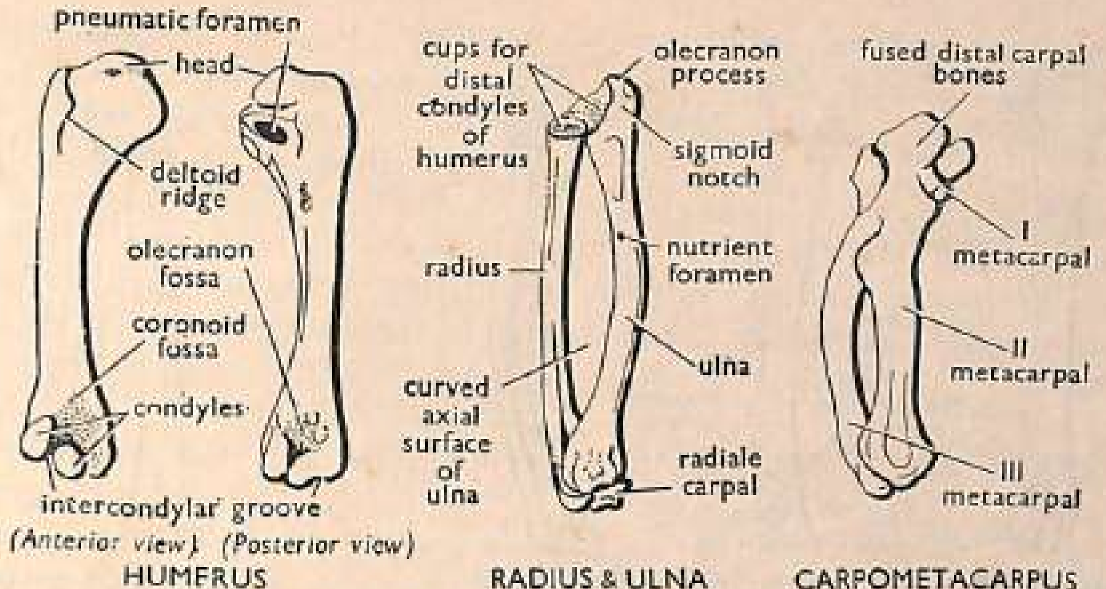


Fig. 6-24. Forelimb bones of Fowl.

3. **Bones of forefoot**—(a) The wrist is made up of 10 small polyhedral rounded bony carpals arranged in two rows. (b) Proximal row contains three carpals namely radiale, ulnare and intermedium. (c) The distal row has 5 carpals. A centrale is found between two rows and a pisciform is attached to the distal epiphysis of ulna. The manus contains five elongated metacarpals and bears 5 digits made up of 2, 3, 4, 5 and 3 phalanges, respectively. Each terminal phalanx contains a horny claw.

FOWL

The forelimb is adapted for flight with the result radius and ulna do not move upon each other, distal carpals fuse with the metacarpals forming carpometacarpus and only three digits are present. Forelimb is composed of **humerus, radius, ulna, carpals, carpometacarpus** and **phalanges.**

1. **Humerus**—(a) It is pneumatic upper arm bone, expanded at both ends. (b) Proximal end contains convex *head*, which contains one smaller pre-axial tuberosity or *delotid* ridge for pectoral muscles and other greater post-axial tuberosity, which contains a large pneumatic foramen, communicating with air space in shaft of bone. (c) Distal end contains two trochlear articular surfaces for radius and ulna.
2. **Radius-ulna**—(a) The *radius* and *ulna* constitute separate bones. (b) *Radius* is straight and slender. The proximal end has a cavity for outer condyle of humerus, while distal knob-like end fits into radiale carpal. (c) Ulna is longer and curved. The proximal end contains a facet for inner condyle of humerus and is produced as *olecranon* process. The distal end articulates with carpals and radius.
3. **Carpals**—*Radiale* articulating with *radius* and *ulnare* articulating with ulna form carpals.
4. **Carpo-metacarpus**—(a) Three metacarpals fuse with distal row of carpals to form *carpo-metacarpus*. The first metacarpal is stumpy, second in the form of straight bone and third slightly curved outwardly.
5. **Phalanges**—Three digits only. The polex or first digit has a single phalanx; index or second digit has two phalanges, while third digit has only one phalanx.

RABBIT

Forelimb comprises of **humerus, radius, ulna** and **bones of forefoot.**

1. **Humerus**—(a) It is a rod-shaped bone. The *head* articulates with glenoid cavity and close to head are outer greater and inner lesser *tuberosities*. (b) Deltoid ridge present. (c) Distally humerus contains a pulley-like *trochlea* to articulate with ulna. (d) Just above trochlea are *coronoid* and *olecranon* fossae.

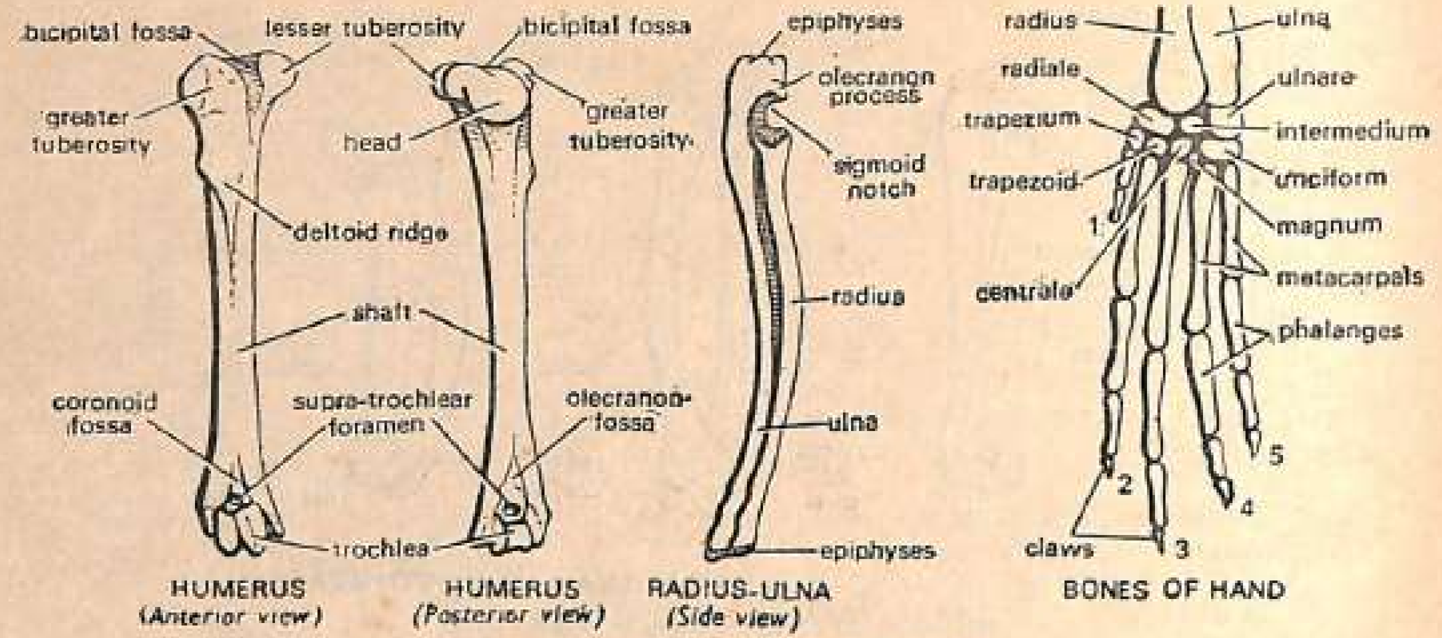


Fig. 6-25. Forelimb bones of Rabbit.

2. **Radius and ulna**—(a) Radius and ulna separate but united firmly at both ends. (b) Radius is smaller and curved. (c) At the proximal end of *ulna* is an *olecranon process*, which articulates with *olecranon* fossa of humerus. At the base of olecranon process is a sigmoid notch which fits into trochlea of humerus.
3. **Bones of forefoot**—The wrist contains nine small bones in two rows, namely *radiale*, *intermedium* and ulnare in proximal row and *single centrale*, *trapezium*, *trapezoid*, *magnum* and *unciform* in distal row. A sesamoid bone or pisciform is found on ventral side of carpus. *Manus* has five digits with 2, 3, 3, 3 and 3 phalanges, respectively. Terminal phalanx has horny claw.

HIND LIMB BONES

FROG

Femur, tibio-fibula, astragalus, **calcaneum** and **foot bones** constitute bones of hind limb.

1. **Femur**—(a) It is thigh bone having expanded ends, covered with calcified cartilages. (b) Proximal end or *head* articulates with acetabulum while distal end with tibio-fibula.

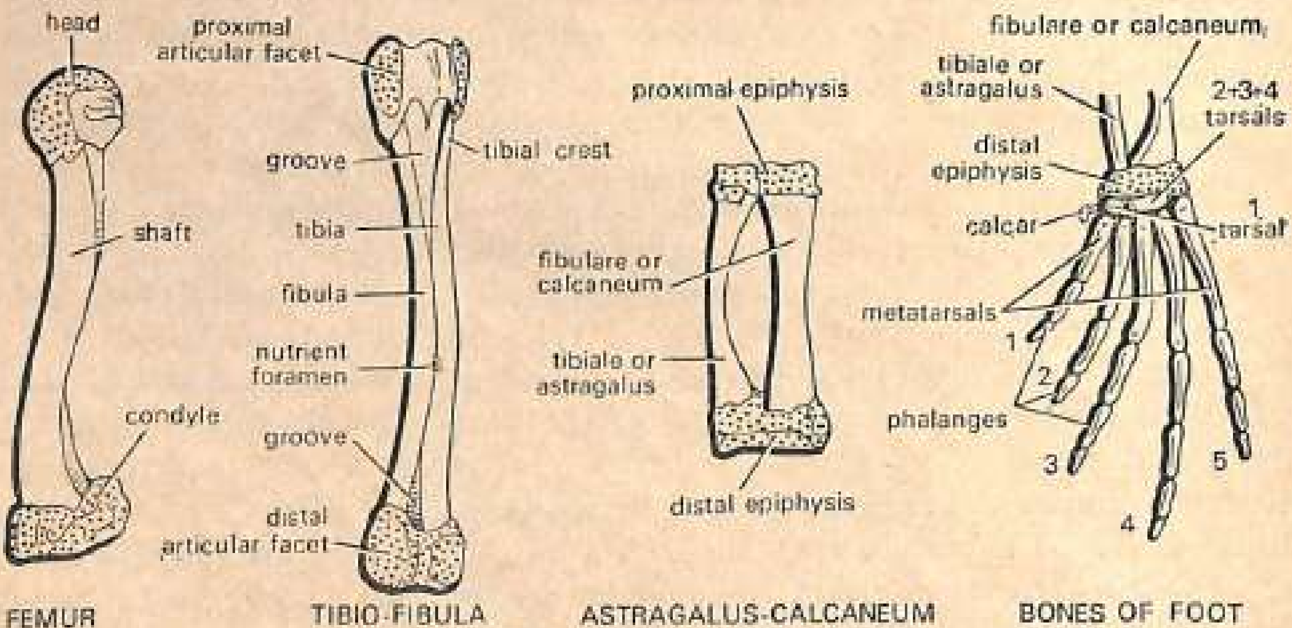


Fig. 6-26. Hind limb bones of Frog.

2. **Tibio-fibula**—(a) These are shank bones and elongated. (b) *Tibia* is inner and *fibula* is outer, both fused together to form a compound bone. Proximally tibia contains a *tibial crest*. (c) At the proximal end tibio-fibula articulates with *femur*, and at distal end with *astragalus–calcaneum*.
3. **Astragalus-calcaneum**—(a) They are proximal ankle bones united at both ends and covered by *epiphyses* of calcified cartilage. (b) The outer thicker straight bone is *calcaneum* or *fibulare*, while inner thinner and slightly curved bone is *astragalus* or *tibiale*.
4. **Bones of foot**—(a) Foot contains 5 long, slender bones, known as *metatarsals*, having five true toes. First, second, third, fourth and fifth digits contain 2, 2, 3, 4 and 3 phalanges respectively. Sixth toe is very small having 2 or 3 bones and is called as *pre-hallux* or *calcar*.

VARANUS

Hind limb consists of **femur, tibia** and **fibula** and **bones of hind foot.**

1. **Femur**—(a) It is thigh bone having two epiphyses. (b) The proximal end contains *head*, which fits into acetabulum, while distal end is pulley shaped, having two tuberosities for articulation with tibia and fibula. (c) Femur has *lesser trochanter* and *greater trochanter* on pre-axial and post-axial sides respectively.

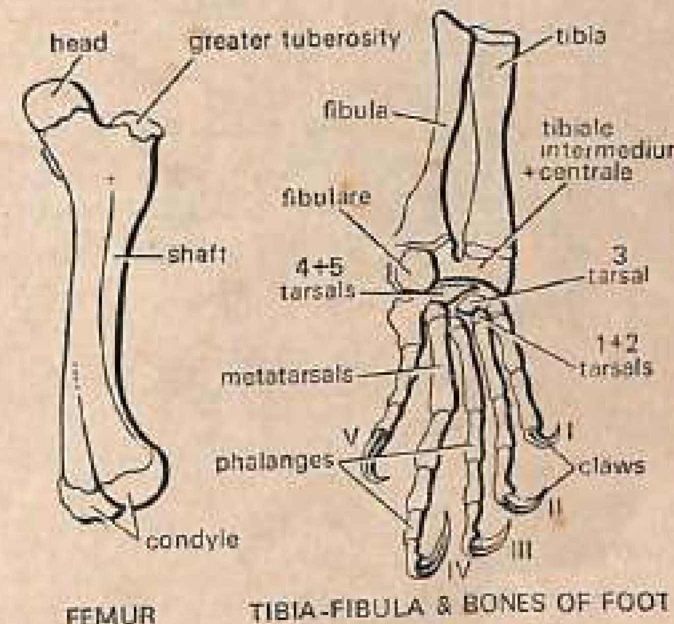


Fig. 6-27. Hind limb bone of *Varanus*.

2. **Tibia and fibula**—(a) These are shank bones. (b) Tibia is stout and curved and is on pre-axial side, while fibula is slender and on post-axial side.
3. **Bones of hind foot**—(a) It is made up of 5 tarsal bones. First, second, third, fourth and fifth toes contain 2, 3, 4, 5 and 3 phalanges respectively, each having a terminal horny claw.

FOWL

Hind limb comprises of femur, tibio-tarsus and fibula, tarsals, tarso-metatarsus and phalanges. Hind limb is modified for bipedal locomotion.

1. **Femur**—(a) It is cylindrical, short and curved thigh bone. (b) *Head* fits into acetabulum and outwardly it contains *greater trochanter*. (c) Distal end is pulley-shaped for *patella* bone and bounded by two condyles to articulate with tibia.
2. **Tibio-tarsus and fibula**—(a) *Tibio-tarsus* and *fibula* form shank bones. (b) *Tibio-tarsus* is straight and long bone and is formed by fusion of tibia with proximal row of tarsals (astragalus and calcaneum). (c) Proximally, it articulates with femur and distally with tarso-metatarsus. (d) Fibula is reduced to small slender bone.
3. **Tarso-metatarsus**—(a) It is a compound bone formed by fusion of distal row of tarsals with second, third and fourth metatarsals. (b) In males tarso-metatarsus bears *fighting spur*.
4. **Phalanges**—(a) Four toes. First or hallux is directed backwards and remaining three forwards. (b) First, second, third and fourth toes have 2, 3, 4 and 5 phalanges respectively; each one is clawed.

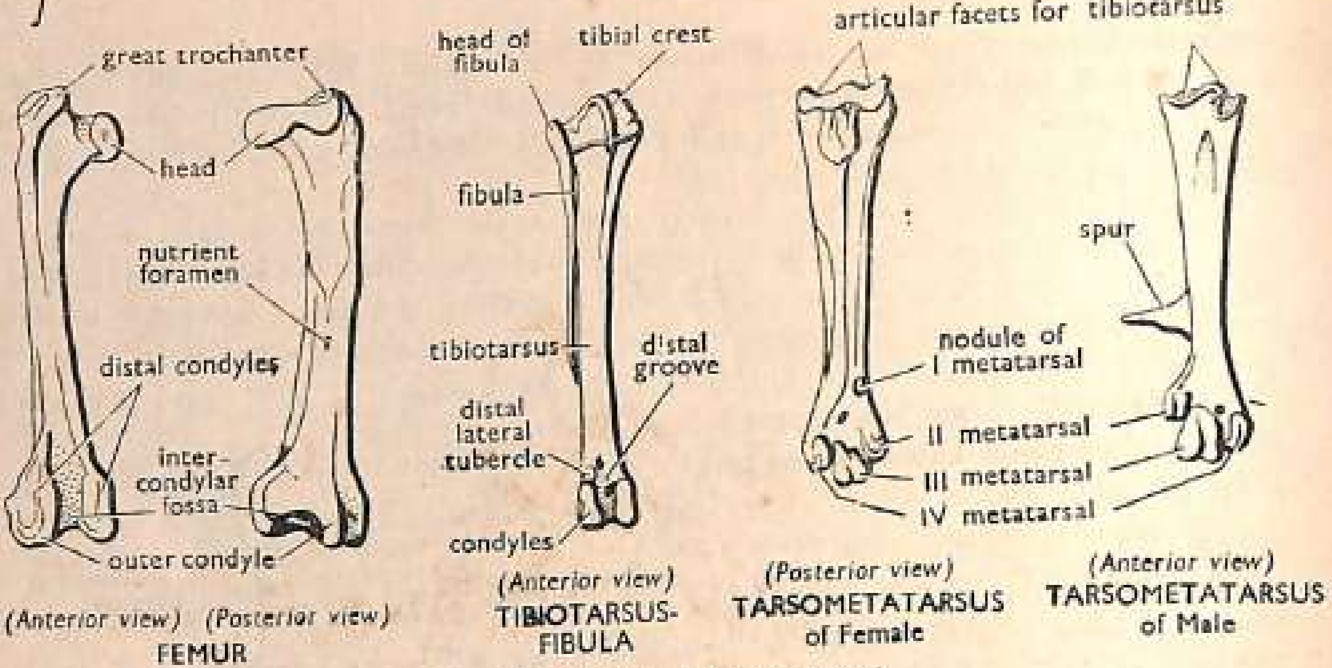


Fig. 6-28. Hind limb bones of Fowl.

RABBIT

Hind limb is formed by **femur, tibio-fibula** and **bones of hind foot.**

1. **Femur**—(a) It is thigh bone. Proximal *head* articulates with acetabulum. (b) Lesser, greater and third trochanters present for muscle attachment. (c) Distally it has pulley-shaped structure, having two lateral condyles which enclose intercondylar groove.
2. **Tibio-fibula**—(a) Tibio-fibula form shank bones, free proximally and united distally. (b) Tibia is large and fibula small.
3. **Bones of hind foot**—(a) It contains six tarsal bones in two rows. (b) The tibiale and intermedium of the proximal row are fused to form astragalus on pre-axial side, while calcaneum is the largest tarsal bone produced into a *spur* on post-axial side. (c) Distal row contains three bones—mesocuneiform, ectocuneiform and cuboid. (d) Only four toes each having three phalanges and each terminal one contains a claw.

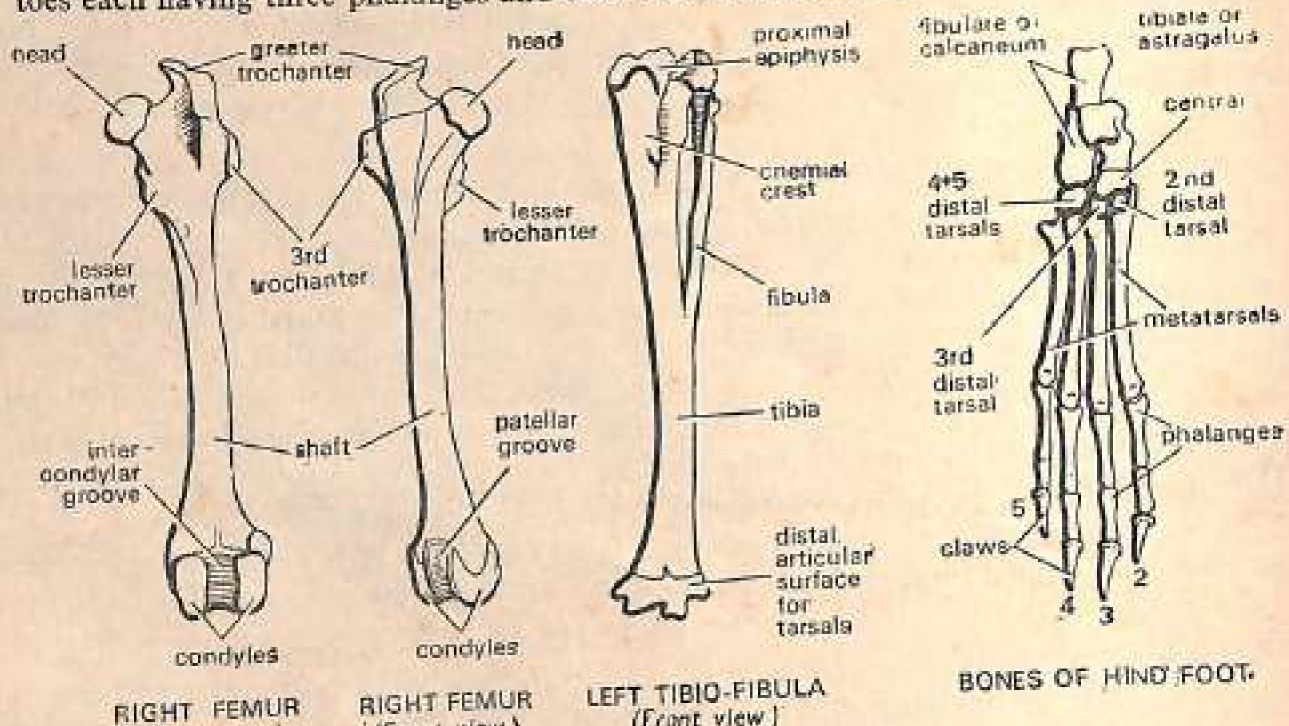


Fig. 6-29. Hind limb bones of Rabbit.

Chapter **7**

Dissections

DOGFISH (*Scoliodon*)

EXTERNAL FEATURES

Take a formalin-preserved or freshly-killed Scoliodon, wash in tap-water and examine the external features. Draw lateral view of the specimen.

Size—It ranges from below 30 cm. to 60 cm. Females are larger than males.

Shape—It is spindle-shaped. The head is dorso-ventrally flattened, while rest of the body is laterally compressed.

Colouration—The back and sides of the body are brownish in colour, while the under-surface is yellowish white.

Texture—The body surface is rough to touch due to backwardly-directed spines of the placoid scales.

Divisions—The entire body is regionated into *head*, *trunk* and *tail*.

(1) *Head—It is flattened and produced into the snout in front of mouth. Note the following structures in the head—*

Mouth—It is crescentic in shape, found on the ventral surface and is guarded by the upper and lower jaws. The jaws contain backwardly-directed conical teeth.

Nostrils—These are obliquely-placed, small apertures on either side of body, anterior to the mouth.

A pair of eyes—Each eye is large and situated on the lateral side of head. It contains upper eyelid, lower eyelid and a thin transparent *nictitating membrane*.

Pores—Several *ampullary pores* are present on the upper and lower surfaces of the head. Each pore opens into the lateral line canal.

Gill slits—There are five gill slits on either side, a little behind the head.

(2) *Trunk—This region constitutes major part of the body starting from behind the gill slits up to cloacal aperture. Trunk contains median impaired fins and paired lateral fins.*

The median fins include—

First dorsal fin—It is found anterior to middle part of the body.

Second dorsal fin—It is found a little behind the first dorsal fin and is a bit smaller than the first.

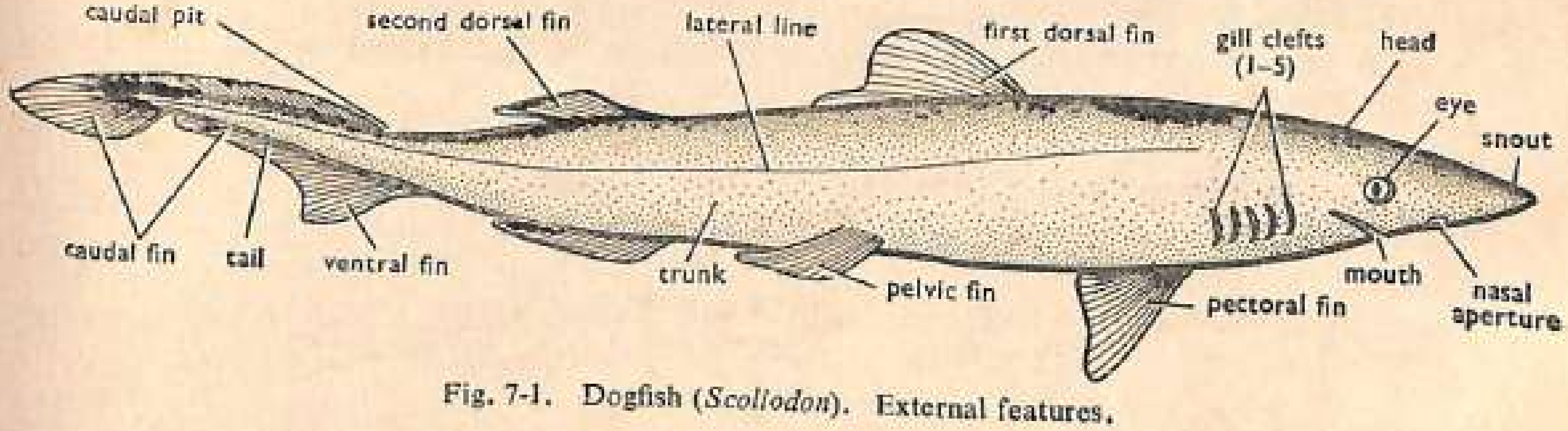


Fig. 7-1. Dogfish (*Scoliodon*). External features.

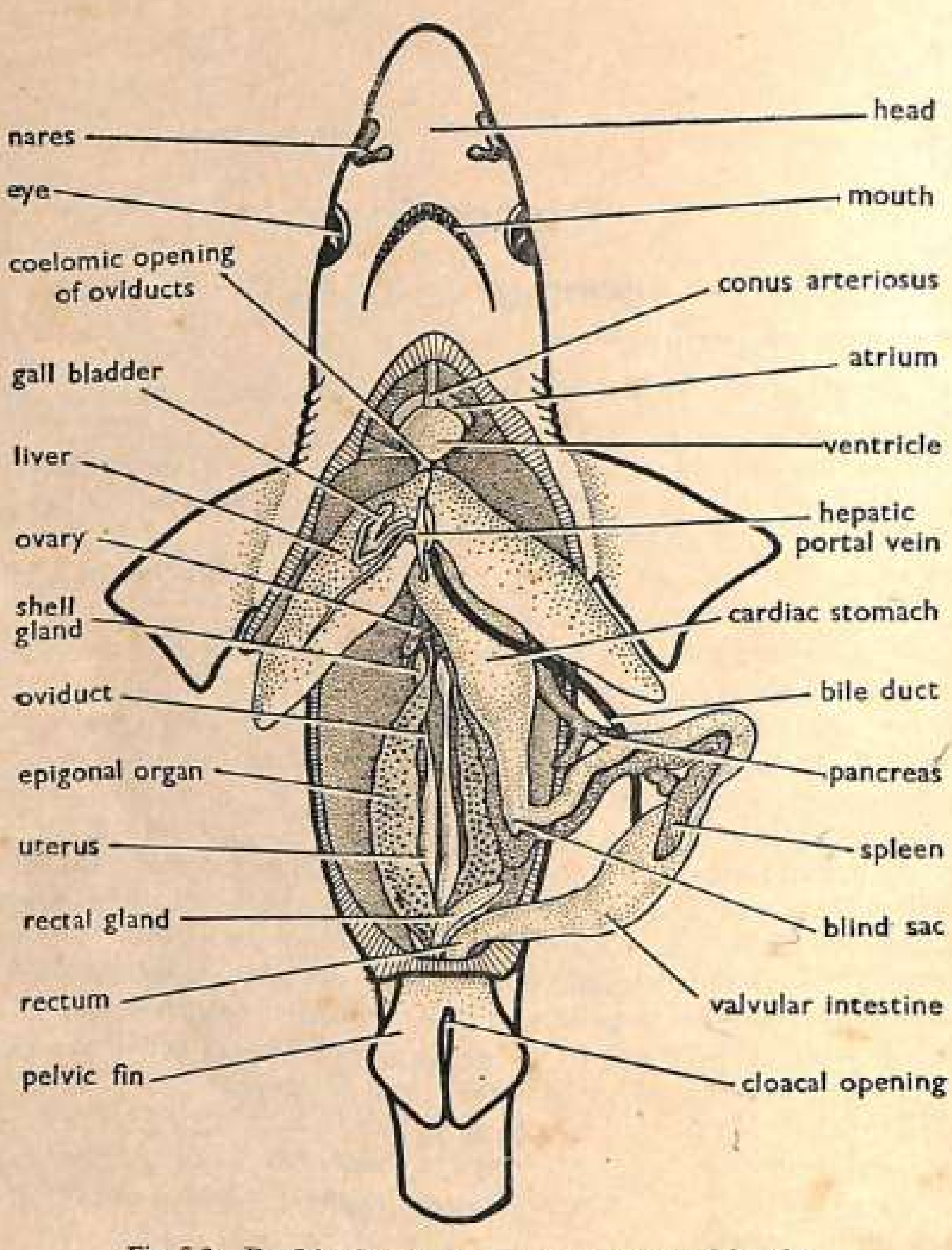


Fig. 7-2. Dogfish (*Scoliodon*). General anatomy of female.

Ventral fin—It is found on the ventral side, at a little distance to the position of second dorsal fin.

The paired fins are—

A pair of pectoral fins—These are large fins found just behind the gill slits and in horizontal plane.

A pair of pelvic fins—These are very small and found on either side of the cloacal aperture.

(3) *Tail*—The portion of the body behind the cloaca is called *tail*. It propels the fish through the water by *caudal fin*. The caudal fin contains *epicaudal* and *hypocaudal lobes*. At the junction of caudal fin and tail is a *caudal pit*.

A pair of *claspers* are found attached to the pelvic fins in males only. Sides of the fish contain faintly-marked *lateral lines*.

GENERAL ANATOMY

Procedure for Dissection

(1) *Take a preserved specimen, wash in water and lay down on the dissecting board with the ventral surface upwards or facing you and fix the animal by pinning the pectoral fin.*

(2) *Make a mid-longitudinal incision in the body wall from the cloacal aperture up to the pectoral girdle and also cut transversally at each end of the longitudinal incision. Reflect and pin down the cut flaps. Examine the following organs—*

Oesophagus—Behind the pharynx is a short oesophagus which leads into the stomach.

Stomach—It is J-shaped and divided into the proximal *cardiac stomach* and distal *pyloric stomach* joined by *blind sac.*

Intestine—Pyloric stomach opens into the wide intestine, which is internally folded into the *scroll valve*, which can be seen by cutting transversally or longitudinally.

Rectum—The intestine leads into the cloaca. A large *rectal* or *caecal gland* opens on the dorsal surface of rectum.

Liver—It consists of two large and elongated lobes ventral to cardiac stomach. The two lobes are anteriorly jointed. *Gall bladder* is found on the dorsal lobe.

Pancreas—It is a bilobed compact gland, situated in the angle between the two limbs of the stomach.

Spleen—It is found in the coils of the pyloric stomach.

Vascular organs—Structures seen are the pericardium, heart (atrium and ventricle), conus arteriosus, ventral aorta and septum transversum.

Male urinogenital organs—These include testes, vasa deferentia, vesiculae seminales, sperm sacs, caecal gland, kidneys, ureters and cloaca.

Female urinogenital organs—The female specimen has ovaries, oviducts with oviducal funnels, epigonal organs, shell glands, uterus, caecal gland, kidneys, ureters and cloaca.

HEART AND AFFERENT BRANCHIAL ARTERIES

For exposing heart and afferent branchial arteries cut through the pectoral girdle and remove its middle portion. Take care not to injure the heart below. Remove the pericardium.

(1) **Heart**—It is a dorso-ventrally bent muscular tube containing four chambers, namely *sinus venosus, auricle, ventricle* and *conus arteriosus.*

(2) **Afferent branchial arteries**—The *conus arteriosus* is continued forward as *ventral aorta* which gives rise to *afferent branchial arteries.*
The *ventral aorta* runs up to the posterior border of the pharynx. Distally it divides into two *innominate arteries.* Each innominate artery again divides into I *afferent branchial artery* and II *afferent branchial artery.* III, IV and V *afferent branchial arteries* originate directly from the ventral aorta at equal distances from each other.
Five pairs of afferent branchial arteries supply to five pairs of gills.

EFFERENT BRANCHIAL ARTERIES

For efferent branchial arteries dissect the fish from the roof of the pharynx.

There are 9 efferent branchial arteries on each side. The I+II, III+IV, V+VI and VII+VIII efferent branchial arteries form four pairs of *loops.* The ninth efferent branchial artery joins with the VIII. The four loops are connected together by longitudinal vessels. Each loop is continued as an *epibranchial artery.* The four pairs of epibranchial arteries unite to form the *dorsal aorta.*

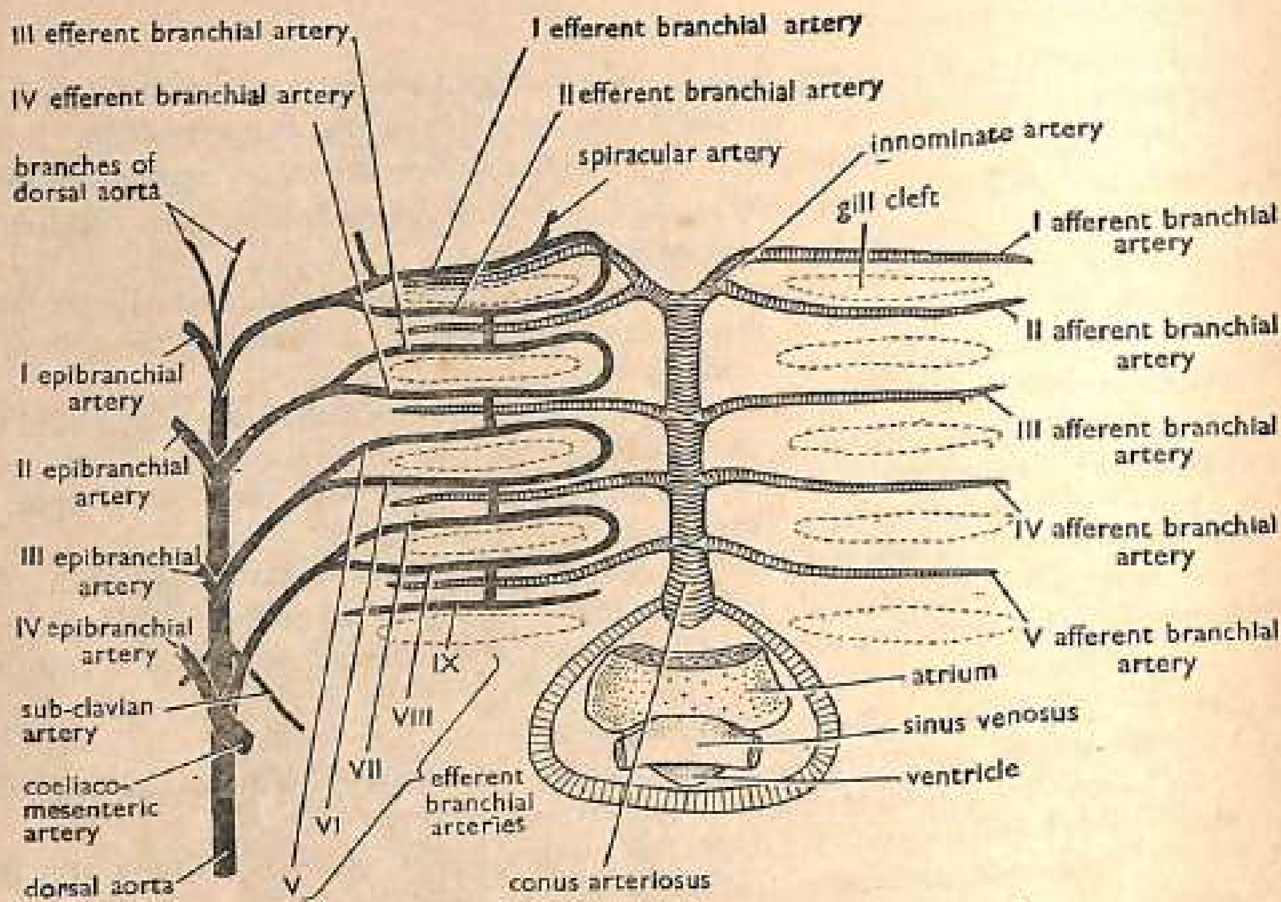


Fig. 7-3. (Dogfish *Scoliodon*). Afferent and efferent branchial arteries.

Also examine some main arteries supplying the head such as the *afferent spiracular artery*, *hyoidean epibranchial artery* and anterior branches of dorsal aorta.

EYE MUSCLES

Remove the eyelids and nictitating membrane to expose the eye-ball and its muscles. The eye muscles are inserted into the eye-ball in two groups. Note the following six eye muscles :

(1) **Superior rectus**—Inserted on the dorsal surface of the eye-ball.
(2) **Inferior rectus**—Inserted on the ventral surface of the eye-ball.
(3) **Anterior rectus**—Inserted on the anterior surface of the eye-ball.
(4) **Posterior rectus**—Inserted on the posterior surface of the eye-ball.
(5) **Superior oblique**—Inserted on the dorsal surface of the eye-ball.
(6) **Inferior oblique**—Inserted on the ventral surface of the eye-ball.

Optic peduncle—It is a cartilaginous stalk holding eye in the orbit.

INTERNAL EAR

Procedure—*The* **internal ear** *or membranous labyrinth lies in the auditory capsule just behind the orbit on either side. The auditory capsules are seen as bulgings on either side. Remove the skin over auditory capsules. Careful observation shows ridges of anterior vertical, horizontal and posterior vertical semicircular canals. The cartilage of auditory capsule can be gently broken by forceps. Take care not to injure the canals of membranous labyrinth. Locate the vertical canals and proceed.*

The internal ear consists of anterior vertical canal, posterior vertical canal, horizontal canal, ampullae of anterior vertical canal, horizontal canal and posterior vertical canal, lagena cochlea, recessus utriculi, utriculus and nerve supplies.

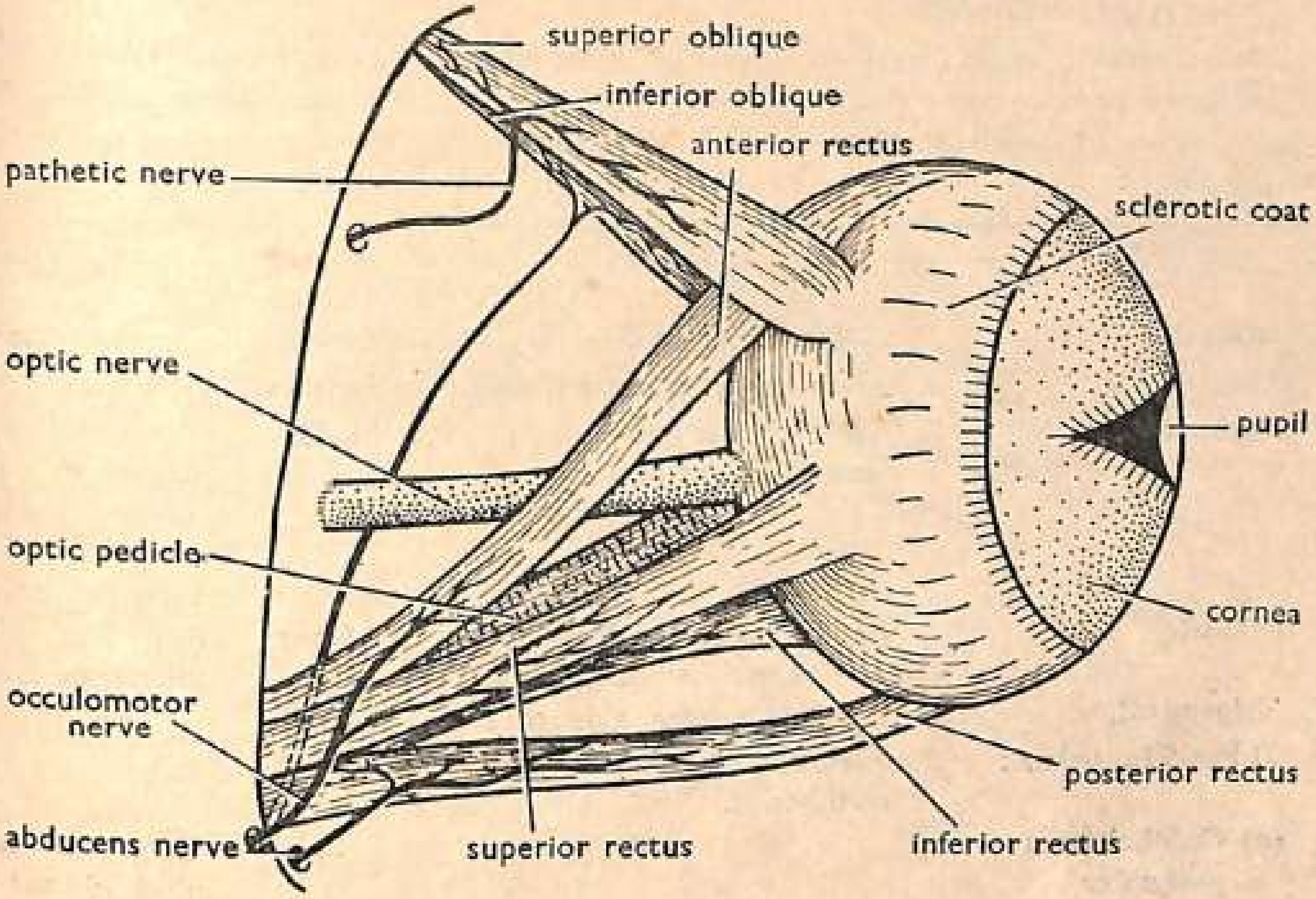


Fig. 7-4. Dogfish (*Scoliodon*). Dissection of eye muscles.

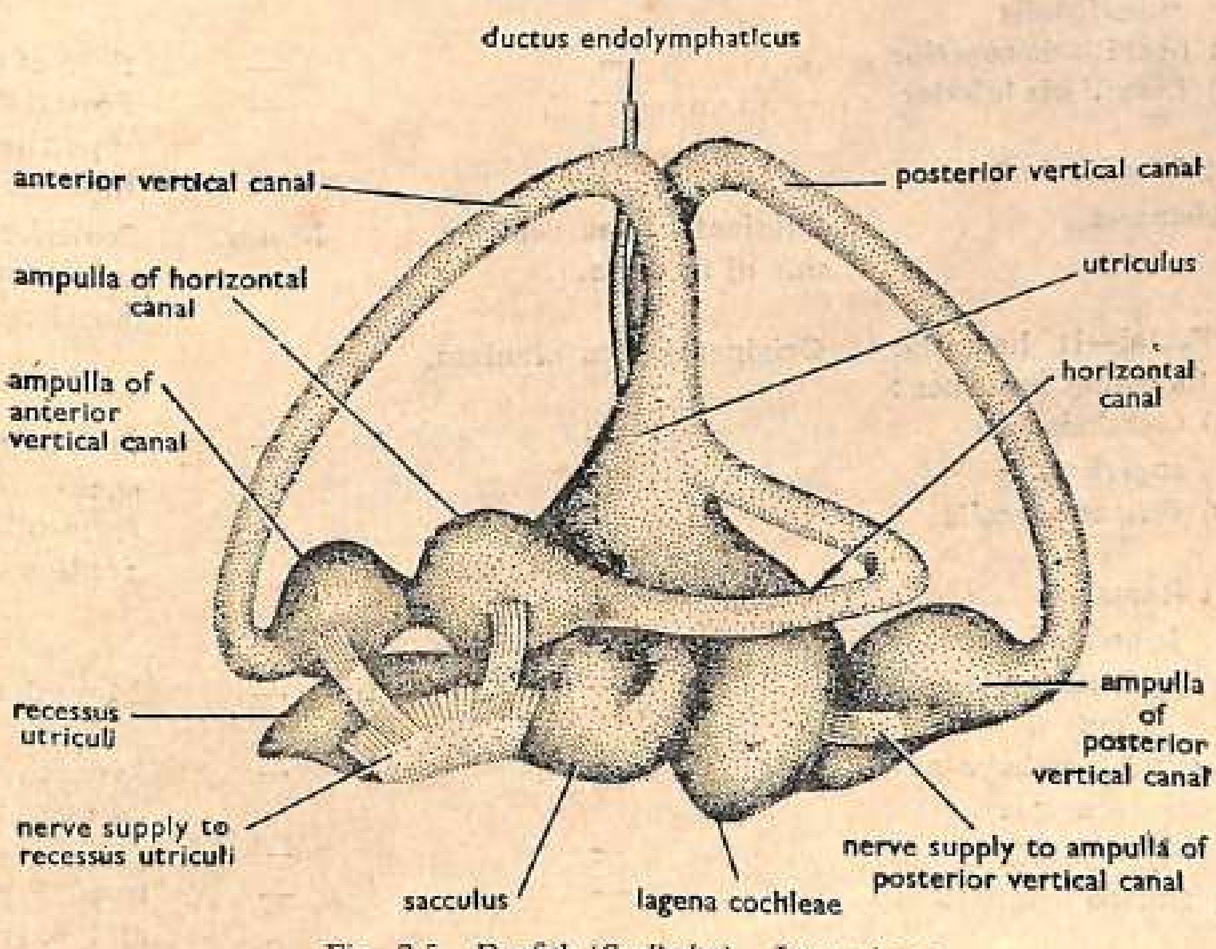


Fig. 7-5. Dogfish (*Scoliodon*). Internal ear.

CRANIAL NERVES

Procedure—*Make a longitudinal incision in the middle of head from the gill cleft region up to the snout and also make transverse incisions on one side up to the lower edges. Remove the flap of skin. There are 10 pairs of cranial nerves emerging from the cranium as given in the following chart :*

No.	Name	Origin	Nature	Innervation
I.	**Olfactory**	Originates from olfactory lobe.	Sensory.	Nose epithelium.
II.	**Optic**	Originates from optic thalamus.	Sensory.	Retina.
III.	**Oculomotor**	Originates from ventral surface of mid-brain.	Motor	Eye muscles (anterior rectus, superior and inferior rectii and inferior oblique).
IV.	**Pathetic**	Originates from dorsolateral side of mid-brain.	Motor	Superior oblique muscle of eye.
V.	**Trigeminal.** It has 5 branches :	Originates from side of medulla just below corpora restiformis.	Mixed.	
	(a) **Ophthalmicus profundus**	—	—	Olfactory capsule and dorsal skin of snout.
	(b) **Ophthalmicus superficialis**	—	—	Skin of snout.
	(c) **Maxillaris superior**	—	—	Skin of upper jaw.
	(d) **Maxillaris inferior**	—	—	Posterior part of upper lip.
	(e) **Mandibularis**	—	—	Muscles : lower jaw.
VI.	**Abducens**	Originates from ventral side of medulla.	Motor.	Posterior rectus and external rectus muscles of eye.
VII.	**Facial**—It has the following branches :	Originates from cranium.		
	(a) **Ophthalmicus superficialis**	—	—	Sense organs of snout.
	(b) **Ramus buccalis**	—	—	Infra-orbital lateral line organ.
	(c) **Ramus hyomandibularis :**			
	(i) **Mandibularis externus**	—	—	Mandibular canal.
	(ii) **Mandibularis internus**	—	—	Mucous membrane of buccal floor.
	(iii) **Hyoidean**	—	—	—
	(d) **Ramus palatinus**	—	—	Roof of pharyngeal and buccal cavity.

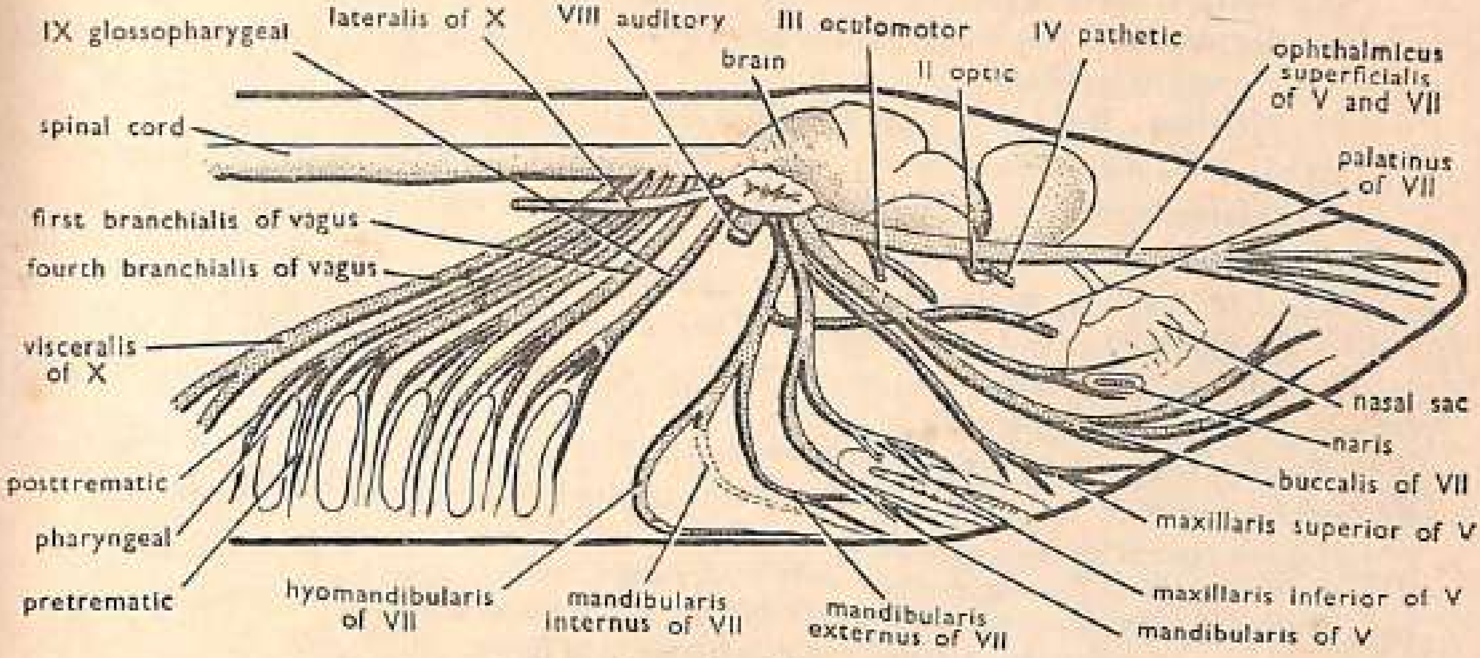


Fig. 7-5. Dogfish (*Scoliodon*). Cranial nerves dissected in lateral view.

No.	Name	Orign	Nature	Innervation
VIII.	**Auditory**	Originates from side of Medulla close to V and VII cranial nerves.	Sensory	Internal ear.
IX.	**Glossopharyngeal** It has 2 branches :	Originates from ventro-lateral side of medulla.		
	(a) **Pre-trematic**	—	—	Mucous membrane, Ist gill slit & pharynx.
	(b) **Post-trematic**	—	—	Muscles of pharynx.
X.	**Vagus**— It has 3 branches :	Originates from side of medulla.		
	(a) **Branchialis**	—	—	Gills.
	(b) **Visceralis**	—	—	Visceral organs.
	(c) **Lateralis**	—	—	Lateral line of trunk.

FROG (*Rana tigrina*)

EXTERNAL FEATURES

Note and examine the following in the living frog :

(1) General body colour (adaptive colouration).
(2) Absence of neck and tail (helps in swimming).
(3) Hind limbs longer than forelimbs, which help in leaping and hopping.
(4) Up and down movements of the floor of the buccal cavity showing respiratory movements.
(5) Distinguish between male and female frogs by copulatory pads in the hand of male.

For detailed external morphology take a frog freshly killed with chloroform vapour. Draw a lateral or dorsal view of the frog. Examine and note the following :

(1) **Size**—*Rana tigrina* measures 12–20 cm. in length.
(2) **Shape**—Roughly it is on triangular plane and adapted for swimming.

(3) **Texture**—Skin is smooth, moist and slippery.

(4) **Colouration**—The dorsal skin is green or olive coloured with dark patches, while ventral is whitish.

(5) **Divisions**—Body is divided into two regions—head and trunk.

Head—*Note the following structures in the head which is conical and having blunt snout :*

(a) **External nares**—These are two small openings lying near the anterior tip of snout.

(b) **Eyes**—They are the most distinct parts of the head. Each eye is large, bright, protuberant, having golden *iris* and black rounded *pupil*. Each eye has an upper large and stationary *eyelid* and a lower small mobile *eyelid*.

(c) **Nictitating membrane**—The upper part of lower eyelid forms a transparent *nictitating membrane*.

(d) **Tympanum** or **tympanic membrane**—It is in the form of a circular area found posterior to each eye. It forms external boundary of the middle ear. The external ear is absent in frog.

(e) **Vocal sacs**—Found in males only under the head.

Trunk—*It forms major portion of the body. Note the characteristic raised hump. Trunk contains anterior forelimbs and posterior hind limbs.*

(a) **Forelimbs**—Each comprises of *upper arm, forearm* and *hand* containing wrist, palm and four digits provided with copulatory and articular pads.

(b) **Hind limbs**—These are folded at rest and each comprises of thigh, shank and foot. Foot is made up of ankle, sole and five digits.

MUSCULAR SYSTEM

Remove the skin of the dorsal surface and note **deltoid, triceps femoris, sartorius, adductor magnus, gracilis major and minor, gastrocnemius, tibialis posticus, extensor cruris, tibialis anticus, rectus abdominis, external oblique, pectoralis** and **mylohoid muscles.**

BUCCO-PHARYNGEAL CAVITY

Open the mouth of the frog as much as you can and note the various structures in the bucco-pharyngeal cavtry.

Mouth leads into *buccal cavity*, which is not sharply divided from *pharyngeal cavity* behind and hence they form common *bucco-pharyngeal* cavity formed by upper and lower jaws.

Maxillary teeth are found in single row in the upper jaw.

Vomerine teeth are found on the roof of upper jaw as two patch-like structures.

Internal nares are found anteriorly in the mouth cavity as two small openings.

Eye-balls bulge in from the roof of the upper jaw as two hemispherical structures.

Openings of the Eustachian tubes are in the form of two circular openings found at the rear of the buccal cavity.

Tongue is long and bifid, attached anteriorly and free posteriorly.

Gullet is found between two jaws and another opening called **glottis** is found below the gullet.

Vocal sacs are found in males having two lateral openings into the mouth cavity.

GENERAL ANATOMY

Procedure—*Kill the frog with chloroform vapours and lay it on its back in dissecting dish. Wash the frog, pin the limbs and press on the pins with the base of the forceps. Add*

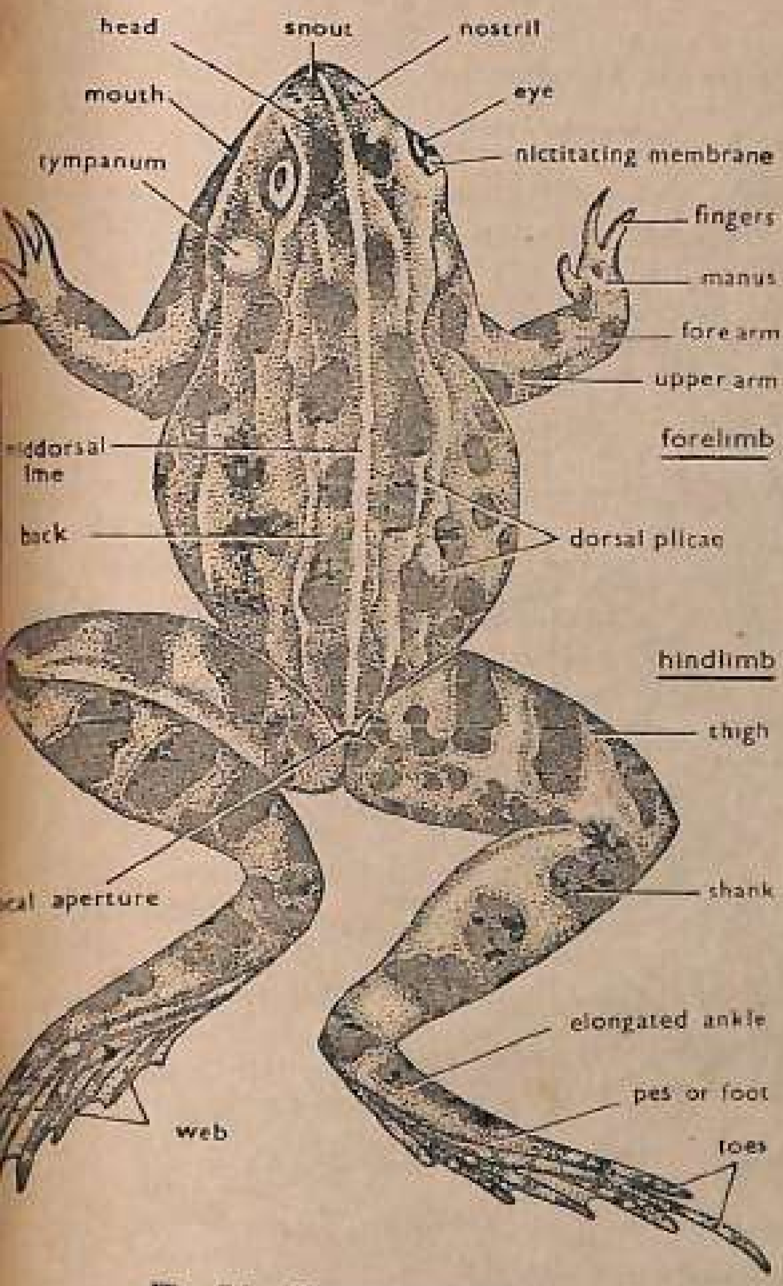


Fig. 7-7. Frog (*Rana tigrina*).
External features in dorsal view.

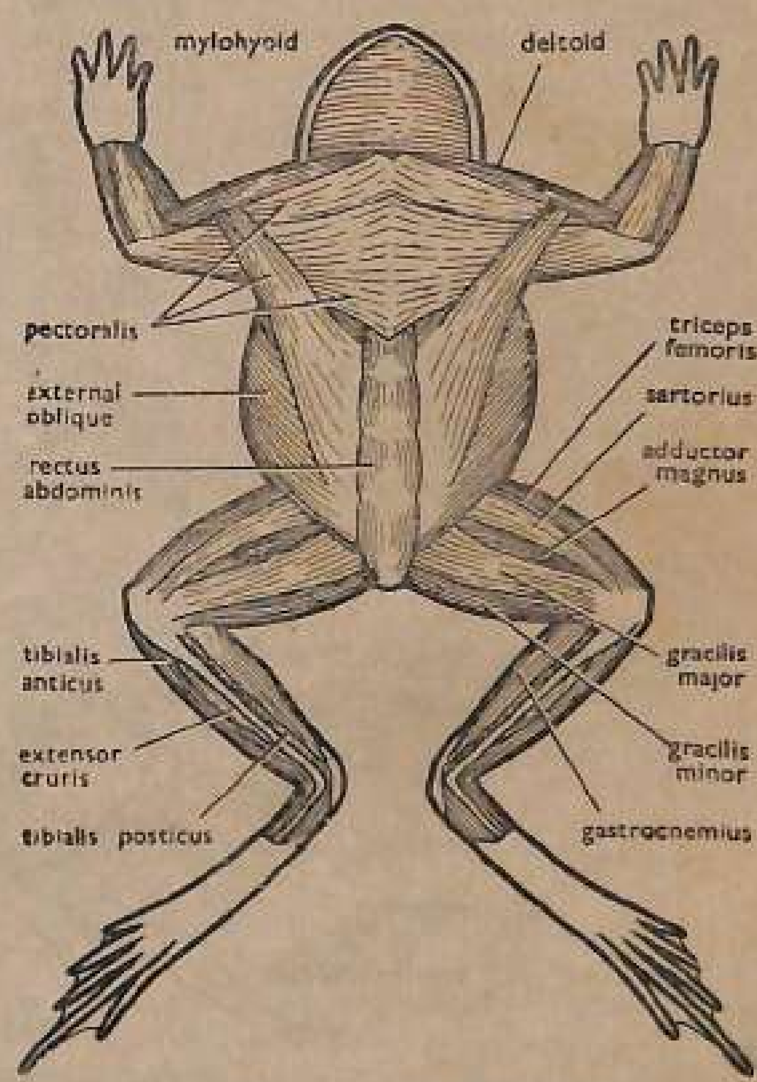


Fig. 7-8. Frog (*Rana tigrina*).
Dissection of muscles.

water in the dish so that frog is completely submerged. Lift the abdominal skin with the forceps and make a mid-longitudinal incision from cloacal region up to the xiphoid cartilage and the pectoral girdle. Cut the skin of thighs to expose the muscles. Students generally cut or puncture the anterior abdominal vein, for which make two incisions on the sides of the abdominal skin. Ligature the anterior abdominal vein near the thighs and at its entrance into the liver and then cut between two ties.

Examine and draw general viscera. Note that all the organs are connected by thin membranes called as mesenteries. Study musculature, lungs, heart, liver, gall bladder, stomach, intestine, spleen, kidneys, fat-bodies, testes in male, ovaries and oviducts in the female and urinary bladder.

Digestive system—The inlet and outlet of the alimentary canal are mouth and cloaca. The *mouth* opening leads into the *bucco-pharyngeal* cavity which is followed by

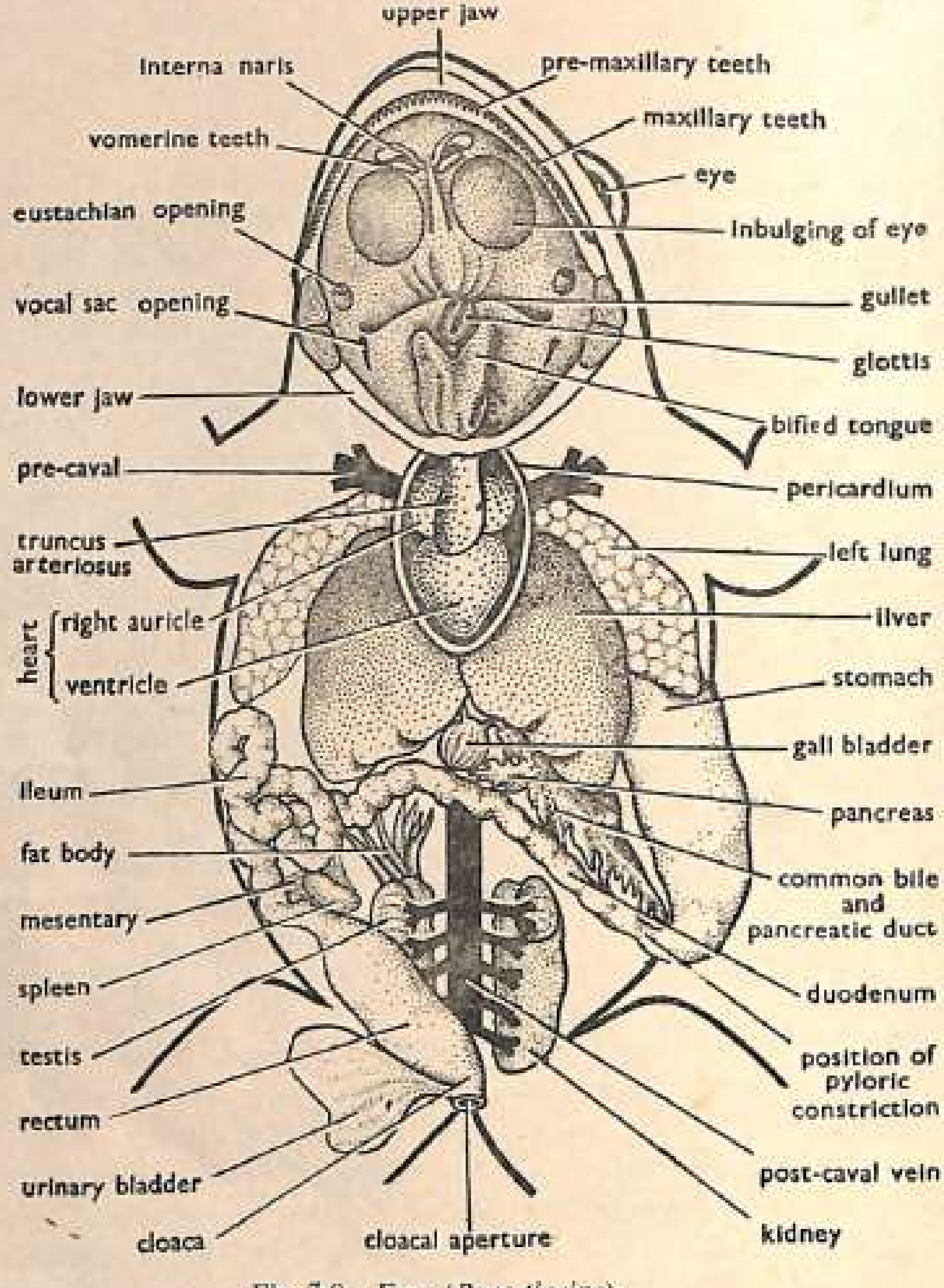


Fig. 7-9. Frog (*Rana tigrina*).
Dissection of buccal cavity and general anatomy (male frog).

a short cylindrical *oesophagus*. The oesophagus opens into the *stomach*, which is muscular curved lying on the left side of the abdominal cavity. It has *cardiac* and *pyloric* ends. The stomach opens into the intestine which comprises of *small intestine* and *large intestine*. The small intestine is called as *ileum* and is thrown into several loops bound by mesenteries. The large intestine is short and straight and consists of the *rectum* which extends backwards and opens into the *cloaca*. The *urinary bladder* also opens into the cloaca. The accessory glands consist of *liver* having two unequal lobes. The two lobes are connected together by a median lobe or *isthmus*. The *gall bladder* lies between the two lobes. The *hepatic ducts* from the liver and *cystic ducts* from the gall bladder unite to form the *common bile duct*, which pierces the pancreas and accompanies the *pancreatic duct* to open with it into the duodenum by a short common *hepato-pancreatic duct* near the pyloric end of the stomach.

CIRCULATORY SYSTEM

The circulatory system of frog comprises of three units—(a) a pumping organ or *heart*, (b) the distributing vessels or *arteries*, and (c) the collecting vessels or *veins*.

A. Heart

Remove pericardium to study the heart.

The heart is S-shaped, triangular, conical and highly-muscularised organ with broad anterior and narrow posterior regions. It is three chambered, containing two *auricles* above and a conical *ventricle* below. The dorsal side of the heart is characterized by pulmonary veins, post-caval vessel and a reduced thin-walled *sinus venosus*. The ventral side contains a tubular *truncus arteriosus*.

B. Venous System (Veins)

Procedure—*Take preferably a freshly-chloroformed and killed frog. Pin in the dissecting dish and open it with ventral surface upwards. The veins, in the dissecting or operating position, lie above arteries. Don't pull unduly skin covering the thorax to the outside so as not to damage the musculo-cutaneous veins. Separate the anterior abdominal vein, tie it at both the ends and cut it in between. Separate alimentary canal from neighbouring organs by cutting mesenteries.*

For renal portal system—*Dissect the frog in the usual way. Separate the anterior abdominal vein and keep it intact. It is formed by the union of two pelvic veins lying in the anterior part of the pelvis. Try to separate the two pelvic veins from the thigh muscles by gently pulling the anterior abdominal vein forwards. Remove the vastus internus muscle lying on the outer side of the thigh to expose femoral vein. By scalpel cut through the pubic symphysis between the two thighs in order to expose the cloaca and two sciatic veins.*

De-oxygenated blood from all parts of the body is collected by the following veins—

Pulmonary veins—These collect oxygenated blood from lungs and open into left auricle. The blood from rest of the viscera is poured into the sinus venosus which, in turn, opens into the right auricle by a sinu-auricular aperture.

Caval veins—The 3 caval veins are :

(1) *Pre-cavals*—Two pre-cavals collect blood from anterior part of the body. Each pre-caval comprises of—

- (i) *External jugular*—It divides into two veins. The *lingual vein* collects blood from tongue and floor of the mouth. The *mandibular vein* collects blood from lower jaw.
- (ii) *Innominate*—It also divides into two veins. The *internal jugular* collects blood from brain and orbit, while *sub-scapular* collects blood from shoulder and back arm.
- (iii) *Subclavian*—It has two branches. The *branchial* collects blood from the arm. The *musculo-cutaneous* collects blood from muscles, abdomen and mucous membrane.

(2) *Post-caval vein*—It receives blood from legs, kidneys, gonads and liver. It comprises of the following vessels :

- (i) *Femoral vein*—It collects blood from outer side of the leg.
- (ii) *Sciatic vein*—It collects blood from inner side of the leg.
- (iii) *Renal portal system*—*Femoral vein* divides into a *renal portal vein* and a *pelvic vein*. The sciatic vein joins with the renal portal vein, which runs on the outer side of kidney and enters kidney to break into several capillaries. The capillaries on emergence from kidney form 4 or 5 *renal veins*. The renal veins of two sides unite with post-caval vein. The double system of blood filtration, one in leg and another in kidneys, is called *renal portal system*. The renal portal vein also receives the *dorso-lumbar vein*, which collects blood from the back muscles.

  The two pelvic veins unite to form an anterior *abdominal vein*, which opens into the left lobe of the liver

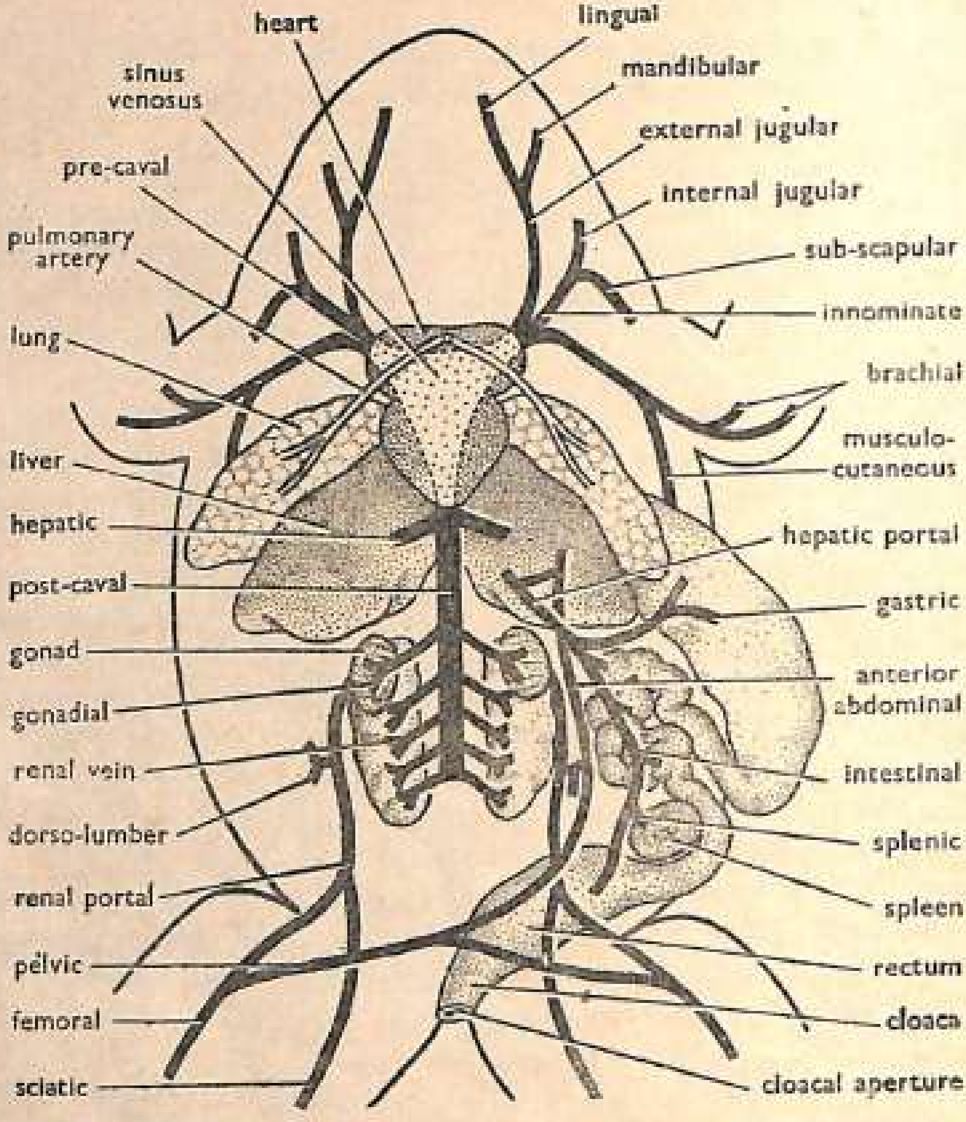


Fig 7-10. Frog (*Rana tigrina*). Venous system.

(iv) *Gonadial veins*—Each vein collects blood from a gonad and receives a small branch from the kidney. The gonadial veins join with the post-caval vein.

(v) *Hepatic veins*—A pair of these, from the liver, joins with post-caval vein.

(vi) *Hepatic portal system*—This system comprises of veins which collect blood from the alimentary canal and communicate with the large *hepatic portal vein*. *A gastric vein* collects blood from stomach, an *intestinal vein* from intestine, a *duodenal vein* from duodenum, a *pancreatic vein* from pancreas, and a *splenic vein* from spleen.

C. Arterial system

The arteries distribute the oxygenated blood to various parts of the body.

Procedure—*Dissect the freshly-killed frog as usual. Separate and tie both the ends of the anterior abdominal vein. Shift the alimentary canal to left hand side and pin it on the dissecting dish. Keep all the mesenteries intact. Tie the anterior vena cava. Lift the heart vertically, the anterior vena cava is seen on the dorsal side of the heart crossing over the three aortic arches of the same side. Insert a fine thread on the anterior vena cava and after encircling it tie with the thread. Cut this vein a little ahead of the tied portion. Cut the pubic symphysis between the two thighs in order to expose the iliac arteries. Follow the branches of the truncus arteriosus.*

The *truncus arteriosus* divides into two branches and each branch on each side gives rise to three main vessels :

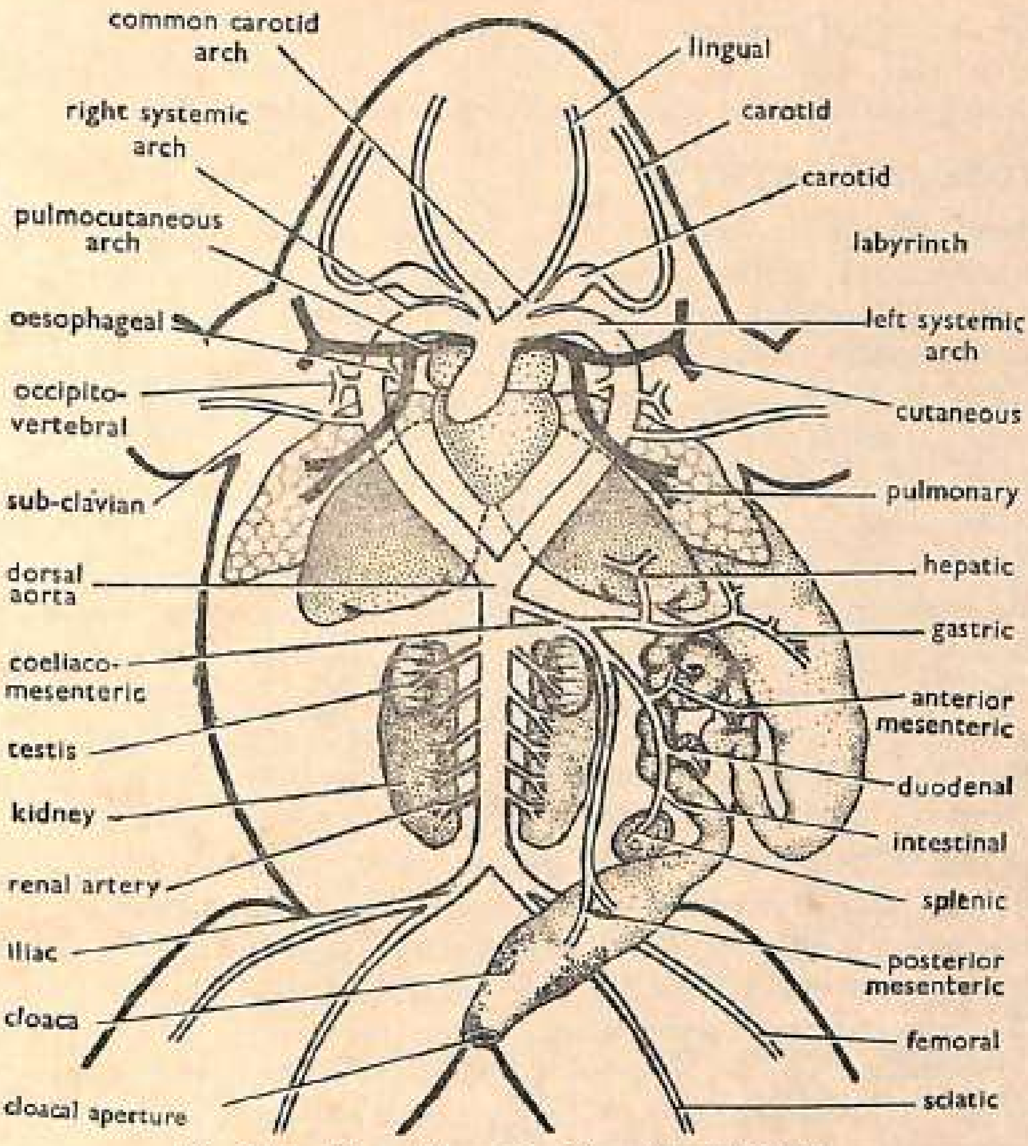


Fig. 7-11. Frog (*Rana tigrina*). Arterial system.

(1) *Pulmo-cutaneous arch*—It divides into two arteries—
   (i) *Pulmonary artery*—It supplies to lung in which de-oxygenated blood is carried.
   (ii) *Cutaneous artery*—It supplies to skin and buccal cavity.

(2) *Carotid arch*—It divides into two arteries—
   (i) *External carotid*—It supplies to tongue and hyoid.
   (ii) *Internal carotid*—It has a swollen *carotid labyrinth* and supplies to orbit and brain.

(3) *Systemic arch*—The two systemic arches encircle around the heart and join together to form the *dorsal aorta*.

Each **systematic arch** gives the following branches :
   (i) *Oesophageal artery*—It supplies to oesophagus.
   (ii) *Occipito-vertebral artery*—It supplies to head, backbone and spinal cord.
   (iii) *Subclavian artery*—It supplies to shoulder and arms.

The **dorsal aorta** proceeds backwards and gives the following vessels :
   (i) *Coeliaco–mesenteric artery*—It divides into two. The *coeliac artery* supplies to stomach by *gastric artery* and to liver by *hepatic artery*. *The anterior mesenteric vessel* has 4 branches—a *duodenal* supplying to duodenum, a *splenic* supplying to spleen, an *intestinal* supplying to intestine, and a *posterior mesenteric* supplying to large intestine.
   (i) *Gonadial artery*—It supplies to gonad.
   (ii) *Renal arteries*—They supply to kidneys.

(iii) *Pelvic artery*—It supplies to urinary bladder.

(iv) *Iliac arteries*—Each iliac divides into two—a *femoral artery* supplying to outer side of the leg, and a *sciatic artery* supplying to inner side of the leg.

URINOGENITAL SYSTEM

1. **Procedure**—*Dissect the frog as usual. Separate the alimentary canal from oesophagus up to the rectum by cutting mesenteries and also cut pubic symphysis to expose the cloaca.*
2. **Male frog**—The urinary and genital organs function together.

   The **urinary system** consists on each side of the following :

   (i) *Kidney*—It is elongated and dark-red coloured with notched edges.

   (ii) *Ureter*—It arises from outer side of kidney and opens into the cloaca.

   (iii) *Seminal vesicle*—It is formed by the dilation of ureter below kidney.

   (iv) *Adrenal gland*—Ventral surface of each kidney has this yellow coloured, elongated gland.

   (v) *Urinary bladder*—It is a bilobed and thin-walled sac, opening into the floor of the cloaca.

   The **genital system** comprises of :

   (i) *A pair of testes*—Attached to anterior kidneys by mesorchium.

   (ii) *Fat bodies*—Finger-like bodies atttached to each testis.

   (iii) *Vasa efferentia*—About a dozen sperm ductules arise from each testis and communicate with collecting tubule of kidney, which opens into the ureter.
3. **Female frog**—The urinary and genital systems function independently and without any communication with each other. The **urinary system** is like that of male frog except that there is no dilation of the ureter in the form of seminal vesicle. The **genital system** is on bilateral pattern. On each side it comprises of :

   (i) *Ovary*—Each ovary is lobulated and attached to the kidney by mesovarium.

   (ii) *Ostium*—It is funnel-like opening into coelom.

   (iii) *Oviduct*—The ostium leads into a coiled oviduct.

   (iv) *Ovisac*—It is found by posterior dilated oviduct. The ovisac opens into the cloaca.

CRANIAL NERVES

10 pairs of these nerves originate from cranium and innervate various organs as illustrated by the following chart :

No.	Name of the Nerve	Origin of Nerve	Type	Innervation
I.	**Olfactory**	From olfactory lobe.	Sensory	Nasal sac epithelium.
II.	**Optic**	From mid-brain ventrally.	Somatic sensory.	Retina of eye.
III.	**Oculomotor**	From floor of midbrain.	Somatic motor.	Eye muscles.
IV.	**Pathetic**	Between optic lobes and cerebellum.	Somatic motor	Eye muscles.
V.	**Trigeminal**— It has 3 branches :	From medulla.	—	—
	(i) **Ophthalmic**	—	Somatic sensory.	Skin and snout.
	(ii) **Maxillary**	—	Somatic sensory.	Skin and upper jaw.
	(iii) **Mandibular**	—	Visceral motor.	Muscles of lower jaw.
VI.	**Abducens**	From floor of medulla.	Somatic motor	Eye muscles.

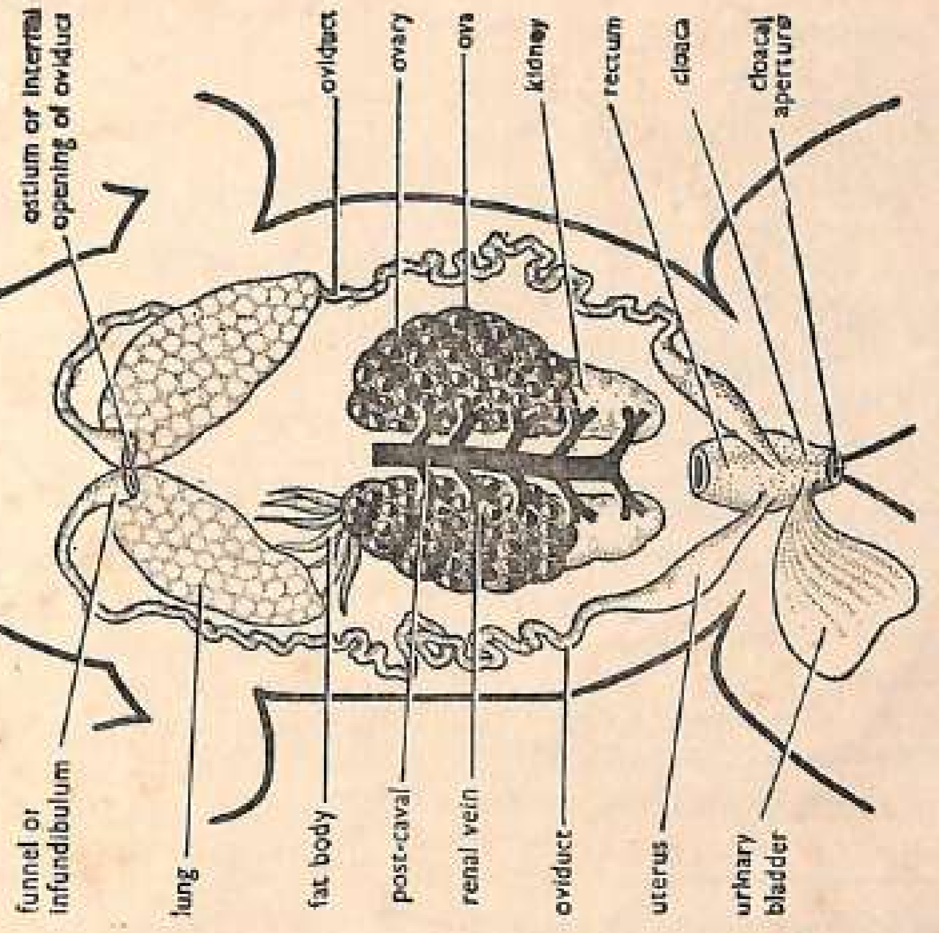


Fig. 7-13. Frog (*Rana tigrina*). Female urinogenital system.

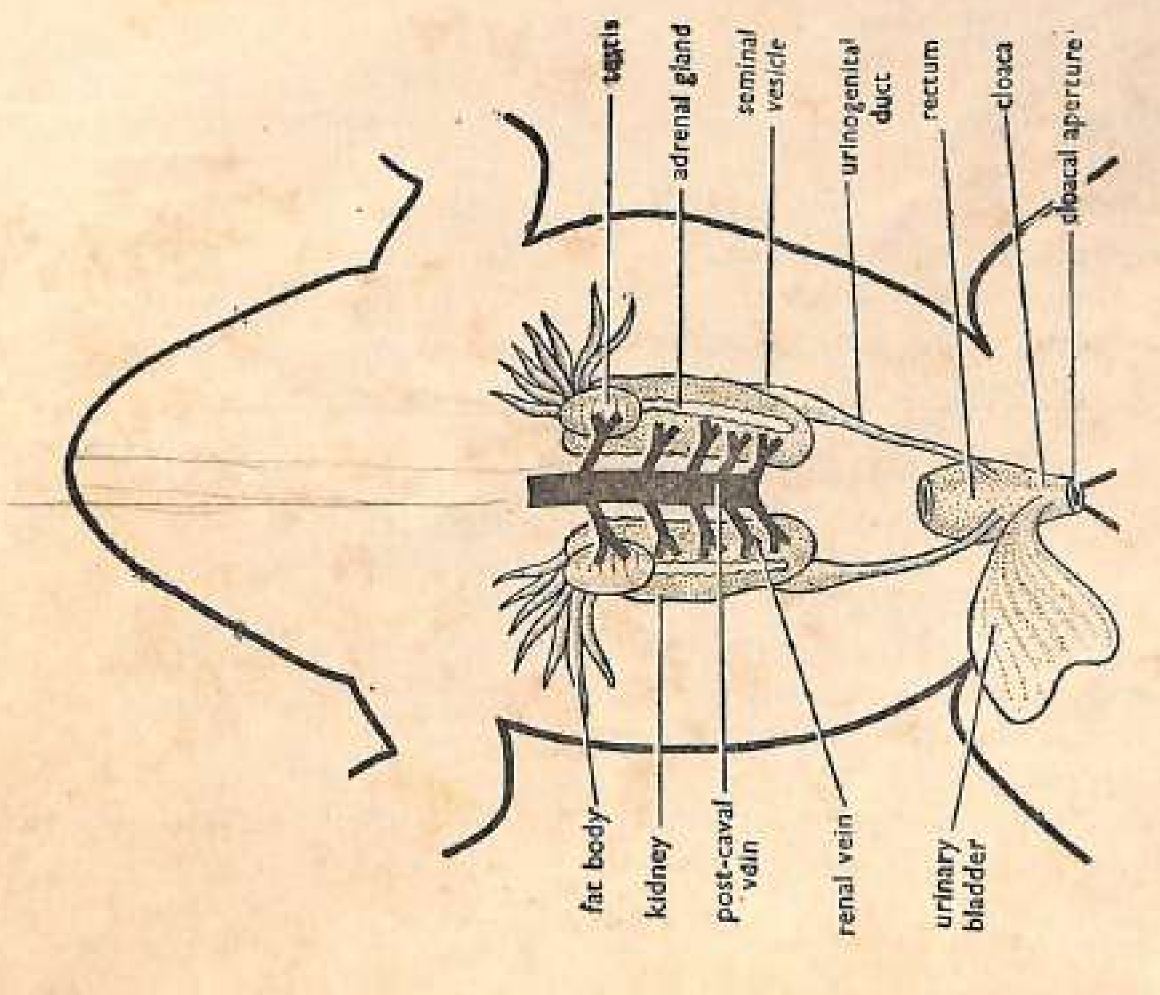


Fig. 7-12. Frog (*Rana tigrina*). Male urinogenital system.

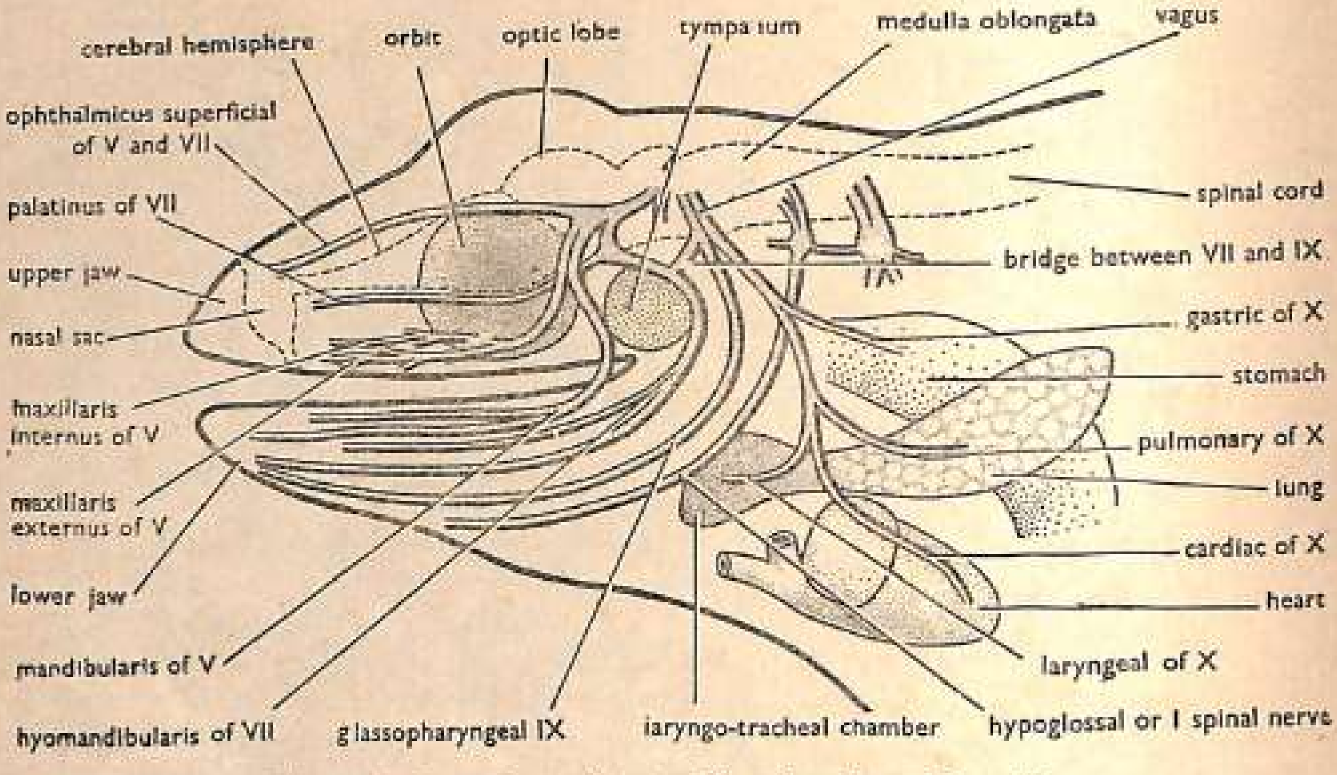


Fig. 7-14. Frog (*Rana tigrina*). Dissection of cranial nerves.

No.	Name of the Nerve	Origin of Nerve	Type	Innervation
VII.	Facial— It has 2 branches :	From medulla.	—	—
	(i) **Palatine**	—	Visceral sensory.	Roof of buccal cavity.
	(ii) **Hyomandibular**	—	Visceral motor.	Tongue, lower jaw muscles and face.
VIII.	**Auditory**	From medulla.	Somatic sensory.	Internal ear.
IX.	**Glossopharyngeal**	From medulla.	Mixed nerve.	Tongue and pharyngeal wall.
X.	**Vagus**	From medulla.	Mixed nerve.	General viscera.

LIZARD (*Uromastix*)

EXTERNAL FEATURES

Take a freshly-killed specimen and examine the external characters. Uromastix is commonly called as "Sanda".

1. *Size*—It measures 20–30 cm. in length.
2. *Shape*—Typically lizard like.
3. *Division*—Body is covered by epidermal scales and regionated into **head, neck, trunk** and **tail.**

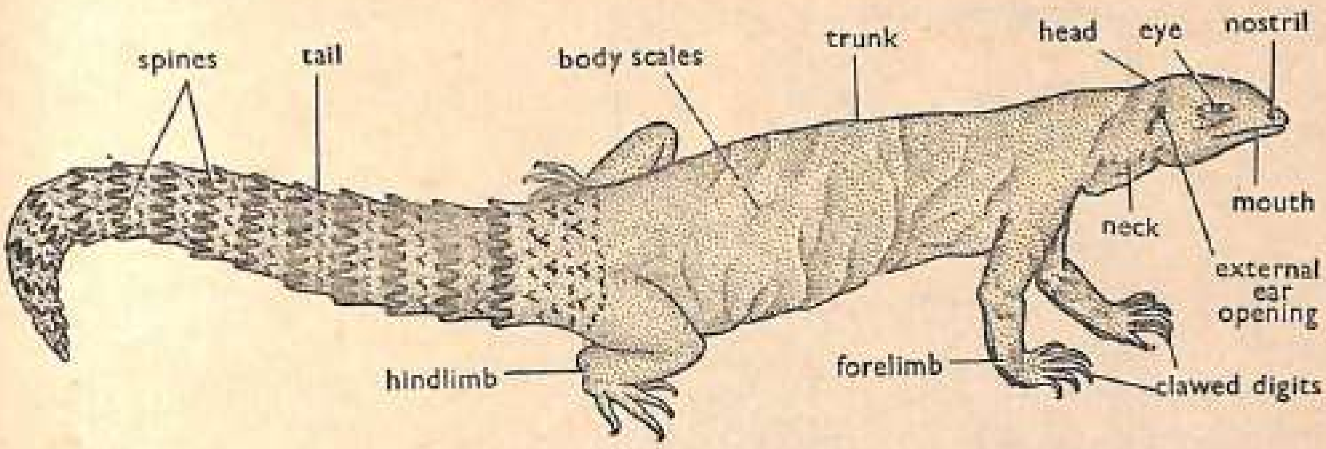


Fig. 7-15. Lizard (*Uromastix*). External features.

4. *Head*—It is small with a short snout and contains the following structures :
   (a) **Nostrils**—The tip of the snout contains two large nostrils.
   (b) **Mouth**—It is a large opening, guarded by upper and lower jaws which contain cutting teeth, one in former and two in latter.
   (c) **Eyes**—Eyes have two movable eyelids and a nictitating membrane.
   (d) **Openings of external ears**—Behind the eyes there are two sunken pits marking opening of external ears. Below each pit is a tympanic membrane, which shows beginning in reptiles of external auditory meatus.
5. *Neck*—It is short.
6. *Trunk*—It is elongated forming major part of the body. It contains 2 pairs of limbs—fore and hind limbs. They are short and primitive and project laterally ending in five digits. Each digit contains a horny claw. The thigh region in males contains 12–18 pores of femoral glands on ventral surface. These glands produce a secretion, which hardens into temporary spines. The spines are used for holding female during copulation.
7. *Tail*—The portion of the body behind cloaca is called tail. The tail is thick and contains about 27 rows of transversally arranged spiny scales.
8. *Penis*—The cloaca has a pair of copulatory hemipenes.

ARTERIAL SYSTEM

Procedure for dissection—*Take a freshly-killed Uromastix with chloroform, wash it in water and lay the lizard on its back in the dissecting dish. Pin the limbs of the lizard. Cover the dish with water. Make a longitudinal incision through the ventral body wall from the cloacal aperture up to the tip of the snout. Cut the sternum and the pectoral girdle. Also make four cuts, two a little posterior to forelimbs and two opposite the hind limbs. Fix the flaps of the skin by pins. Cut very carefully the connecting membranes so as not to injure any organ and blood vessels. Cut the pericardium and trace the blood vessels first veins and then arteries.*

The blood is distributed to all parts of body by the following arteries :

1. **Pulmonary arteries**—The pulmonary aorta originates from the right side of the ventricle and it divides into two pulmonary arteries, each going into a lung. They carry impure blood to lungs.
2. **Systemic arches**—The truncus arteriosus divides into right and left systemic arches. Right arch originates from the left side of the ventricle and left arch from the right side. Systemic arches give various arteries.

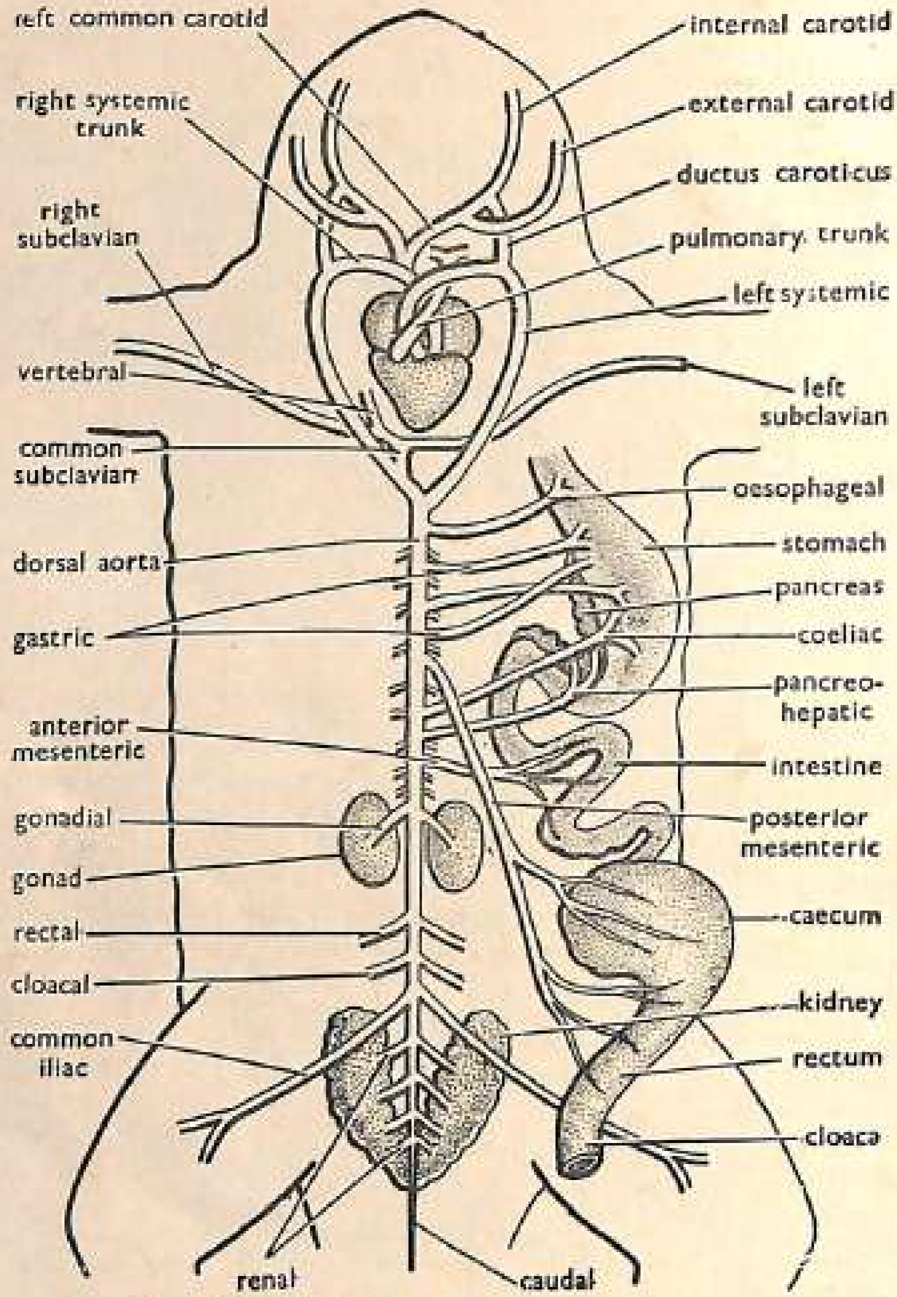


Fig. 7-16. Lizard (*Uromastix*). Arterial system.

(i) *Innominate artery*—It originates from the right systemic arch, which divides into the *right carotid* and *left carotid arteries*. Each carotid divides into an *internal carotid* and an *external carotid*.

(ii) *Ductus caroticus*—It joins the internal carotid artery with systemic arch of its sides.

(iii) *Subclavian artery*—It originates from the right systemic arch and divides into right and left *subclavian arteries* which supply to arms. A *vertebral* branch from right subclavian supplies to vertebrae.

3. **Dorsal aorta**—The right and left systemic arches unite together forming dorsal aorta, which proceeds backwards to supply by several arteries to viscera.

(i) *Oesophageal artery* to oesophagus.

(ii) *Paired gastric arteries* to stomach.

(iii) *Coeliac artery* to stomach and spleen.

(iv) *Pancreo-hepatic artery* to pancreas and liver.

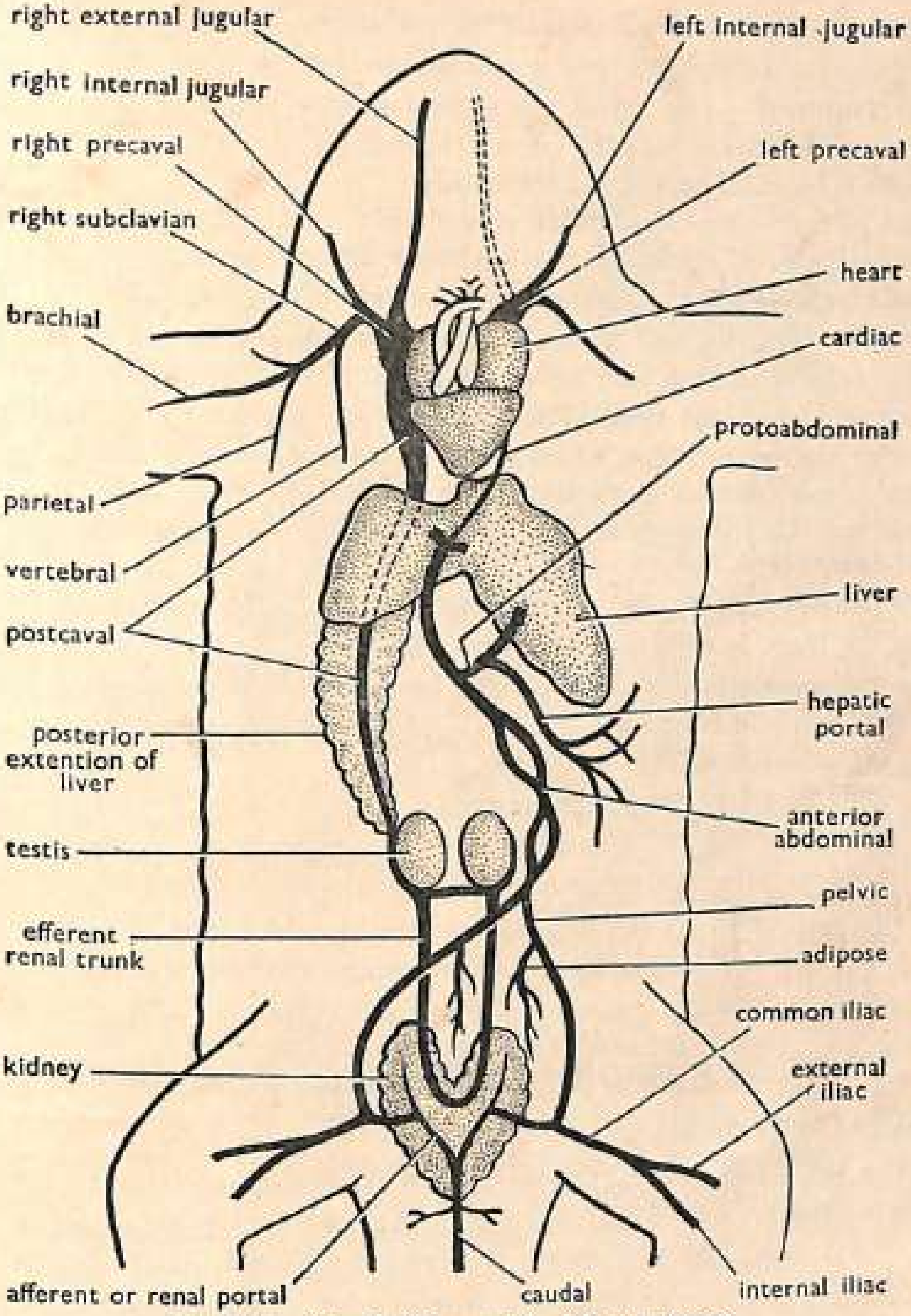


Fig. 7-17. Lizard (*Uromastix*). Venous system.

(v) *Anterior mesenteric artery* to ileum. (vi) *Posterior mesenteric artery* to caecum. (vii) *Gonadial artery* to gonad. (viii) *Cloacal arteries* to cloaca. (ix) *Renal arteries* to kidneys. (x) *Caudal artery* to tail. (xi) *Iliac arteries* to legs.

VENOUS SYSTEM

The blood from the entire body is collected by the following veins :

A. Pulmonary veins—Collect oxygenated blood from lungs. They unite and open into the left auricle.

B. Pre-caval veins—Each pre-caval vein collects blood from the anterior end, by the following veins :

1. **External jugular**—Collects blood from neck.
2. **Internal jugular**—Collects blood from head.
3. **Subclavian**—Collects blood from the arm.

Note that there is no external jugular on the left side and left pre-caval contains only internal jugular and subclavian. The two pre-cavals enter the bilobed sinus venosus.

C. **Post-caval vein**—The blood from the posterior region is collected by post-caval vein, which pours blood into the sinus venosus. The posterior veins are—

(1) **Caudal vein**—Collects blood from tail.

(2) **Renal portal vein**–The caudal vein divides into kidney to form renal portal veins.

(3) **Femoral vein**—Collects blood from outer side of leg.

(4) **Sciatic vein**—Collects blood from inner side of leg.

(5) **Iliac vein**—It is formed by the union of femoral and sciatic veins.

(6) **Pelvic vein**—On each side renal portal and iliac veins unite to form a pelvic vein.

(7) **Anterior abdominal vein**—The two pelvics imperfectly unite together to form anterior abdominal vein, which opens into the left lobe of the liver.

(8) **Renal sinus vein**—The capillaries in the kidney unite to form renal sinus vein, which extends forwards as *efferent renal trunk*.

(9) **Post-caval vein**—The two efferent renal trunks unite together below gonad and form the post-caval vein. The post-caval vein, after receiving a wide *hepatic vein* from the liver, is continued upwards and opens into the sinus venosus.

(10) **Hepatic portal system**—It is formed by the following veins—

(i) *Gastric vein* from stomach.

(ii) *Intestinal vein* from intestine.

(iii) *Duodenal vein* from duodenum.

(iv) *Splenic vein* from spleen.

(v) *Pancreatic vein* from pancreas.

These veins unite to form the hepatic portal vein, which joins with abdominal vein and enters the liver, where it breaks into capillaries forming hepatic portal system.

ROCK PIGEON (*Culumba livia domestica*)

EXTERNAL FEATURES

In order to study external morphology, take freshly chloroformed pigeon. Note that entire body, except the beak and feet, is covered by feathers. Body is regionated into *head*, *neck*, *trunk* and *tail*. The size and colour of the body vary in different species and varieties.

(1) **Head**—It contains several structures—

(i) *Beak* or *bill*—It is strong, horny, straight and pointed. At the base of the beak is a naked swollen portion of sensitive skin called *cere*.

(ii) *External nares* or *nostrils*—These are obliquely situated in the cere.

(iii) *Eyes* and *eyelids*—Each eye is large and surrounded by *upper eyelid*, *lower eyelid* and a *nictitating membrane*.

(iv) *External auditory aperture*—It is posterior to each eye and is covered by backwardly directed feathers, the *auriculars*.

(2) **Neck**—It is long, flexible and S–shaped.

(3) **Trunk**—It constitutes major part of body. It is divided into a large *thorax* and a small *abdomen*. The thorax is strengthened ventrally by the large *sternum*, from which projects *carina* or *keel*. The keel is seen and felt as a prominent ridge. Trunk contains 2 pairs of *limbs*.

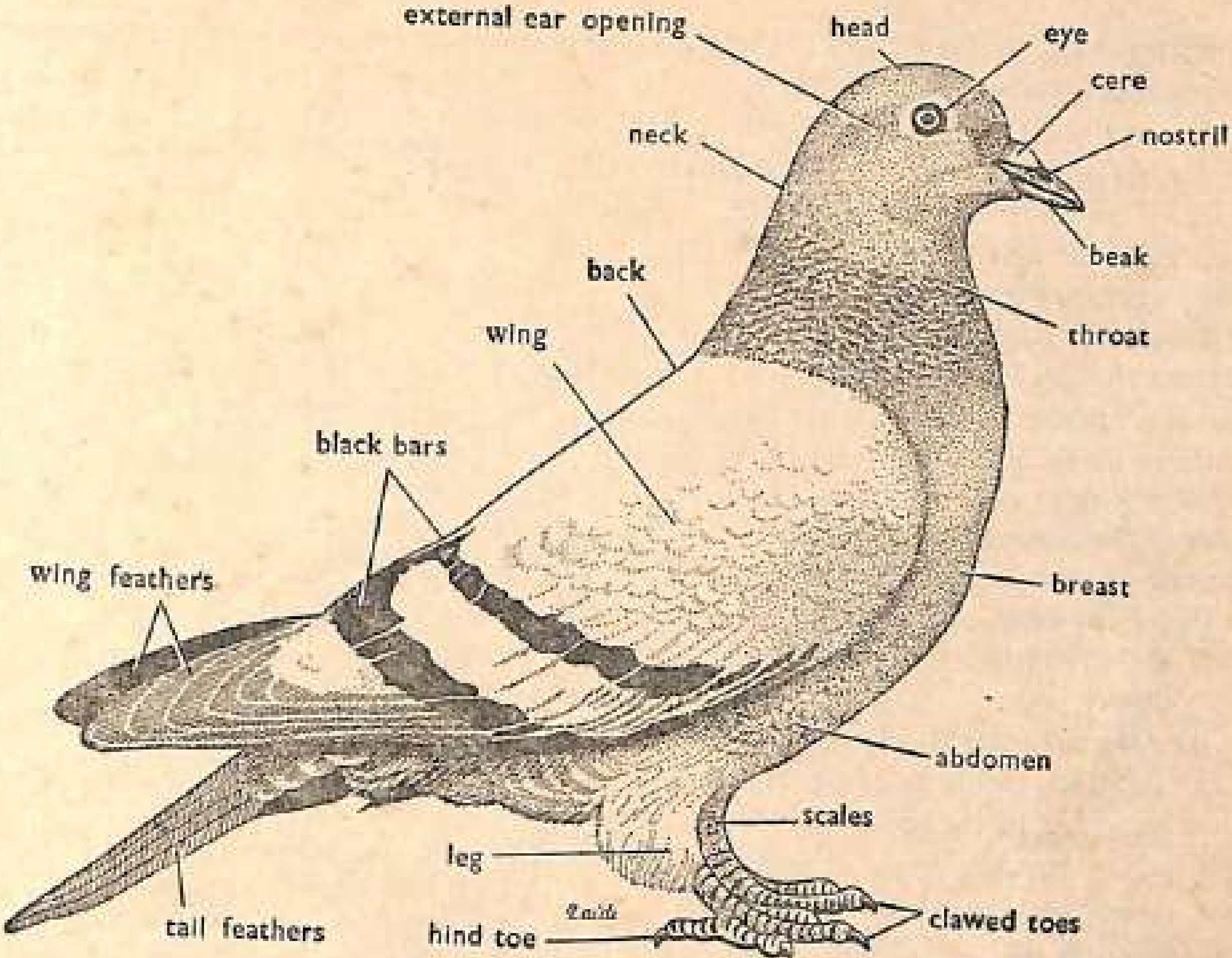


Fig. 7-18. Rock pigeon (*Culumba livia domestica*). External features.

(i) *Forelimbs*—These are modified into *wings*. Each wing is divided into the *upper arm, forearm* and *hand*. There are two *alar membranes*. One is *pre-patagium*, which extends between upper arm and forearm and the other is called *post-patagium* which is smaller, extending between the upper arm and trunk.

(ii) *Hind limbs*—They support the body and are modified for bipedal locomotion. The hind limbs contain horny scales and each digit has a horny *claw*.

(4) **Tail**—The region behind *cloaca* is called tail. The dorsal surface of the tail contains a *uropygial gland* secreting *oil*. Squeeze this gland and note oil oozing from it. The oil is used to dress or preen its feathers.

(5) **Feathers**—Feathers cover more or less the entire body. They are of three kinds—

(i) *Contour feathers*—They cover the surface of the body. The strongest contours are the *quill feathers*. The quill feathers of wings are called *remiges* and of tail as *rectrices*. The remiges attached to bones of **hand** are called *primaries* and to **ulna** as *secondaries*. A small bunch of feathers is attached to the first pre-axial digit called *ala spuria* or *bastard wing*.

The axis of the quill feather is divided into naked basal *calamus* or *quill* and upper *rachis* or *shaft* surrounded by the *vexillum* or *vane*. The vane contains obliquely arranged *barbs* on the two sides of the rachis. The barb carries two rows of *barbules* arranged on both sides. Barbules of adjacent barbs are fastened together by *hooks*.

(ii) *Hair-feathers* or *Filoplumes*—These are very thin, hair-like and degenerate feathers, situated at the base of the contour feathers.

(iii) *Down feathers*—They are found below contour feathers and do not contain hooks on the barbules.

GENERAL ANATOMY

Procedure—*Cut longitudinally the abdominal wall from the cloaca. By strong scissors make a cut through the sides of sternum along its attachment to the ribs and lift the sternum with the fingers, so as not to injure the internal organs. Disarticulate the coracoids from the sternum and also cut the furcula at the two clavicles. The sternum can be detached to expose fully the underlying organs. Draw the diagram of the organs seen in situ.*

(1) Bucco-pharyngeal cavity—

(i) *Horny beak*—It encloses the front parts of upper and lower jaws.

(ii) *Internal nares*—These are slit-like openings, lying close together in the roof.

(iii) *Eustachian opening*—It is a single aperture found just behind the internal nares.

(iv) *Tongue*—It is triangular and pointed.

(v) *Glottis*—It lies posterior to the tongue.

(2) Digestive System—

(i) *Oesophagus*—It is large, wide and elongated. It extends through neck dorsal to the trachea and forms a *crop* in the middle.

(ii) *Stomach* — The oesophagus opens into the stomach. It comprises of a small digestive *proventriculus* and a large mechanical *gizzard* which is highly muscular.

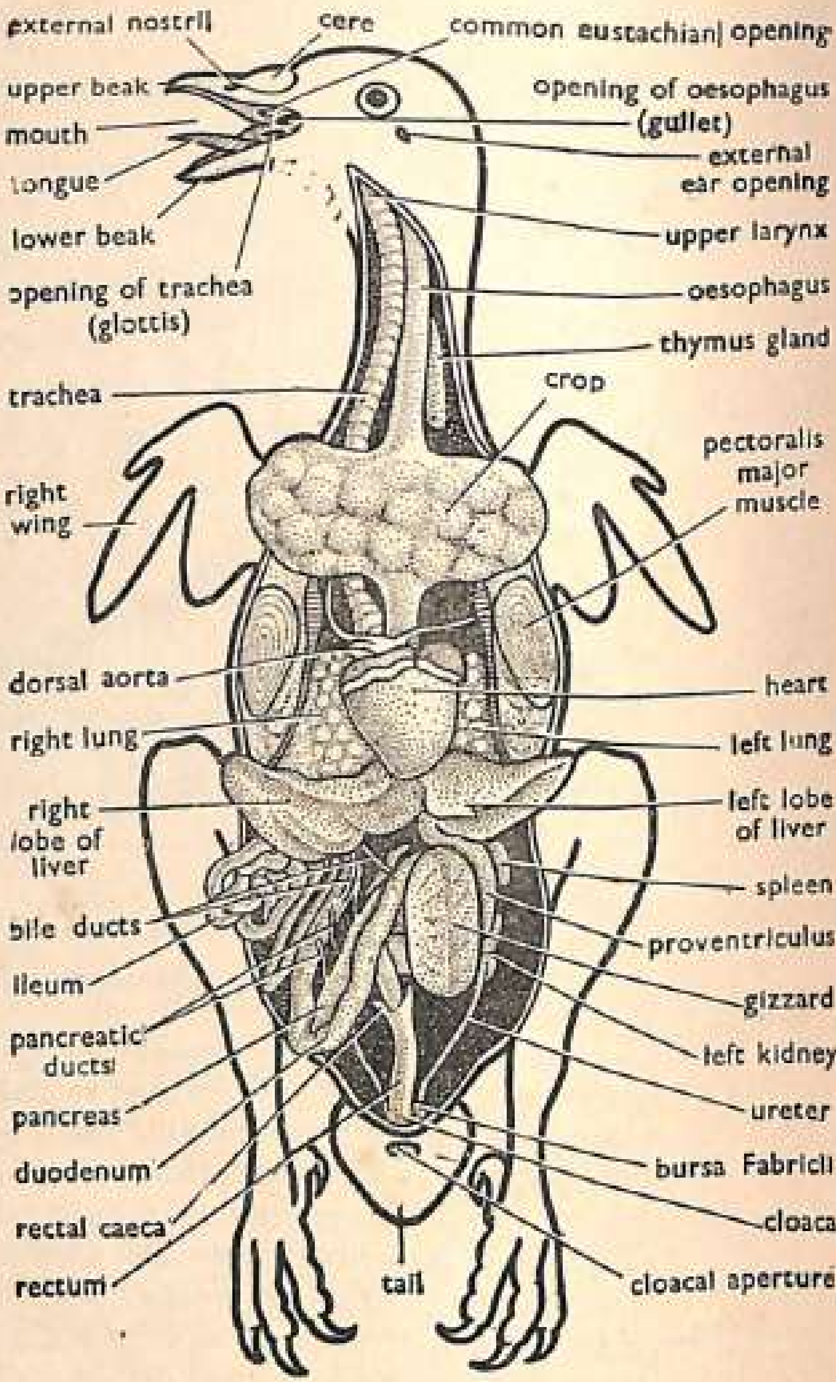


Fig. 7-19. Rock pigeon. Dissection of general anatomy.

(iii) *Intestine*—Stomach leads into the intestine, which is differentiated into the *duodenum*, *ileum* and *rectum*.

(iv) *Associated glands*—These comprise of *liver*, *pancreas* and *spleen*.

(3) Respiratory system—It consists of—

(i) *Upper larynx*—It opens into the pharynx by glottis.

(ii) *Trachea*—It is situated ventral to the oesophagus and is supported by partially ossified rings. The trachea leads into lungs and *air sacs* by bronchii.

Insert a blow pipe in trachea and inflate the air sacs Tie a thread in trachea and examine the following air sacs :

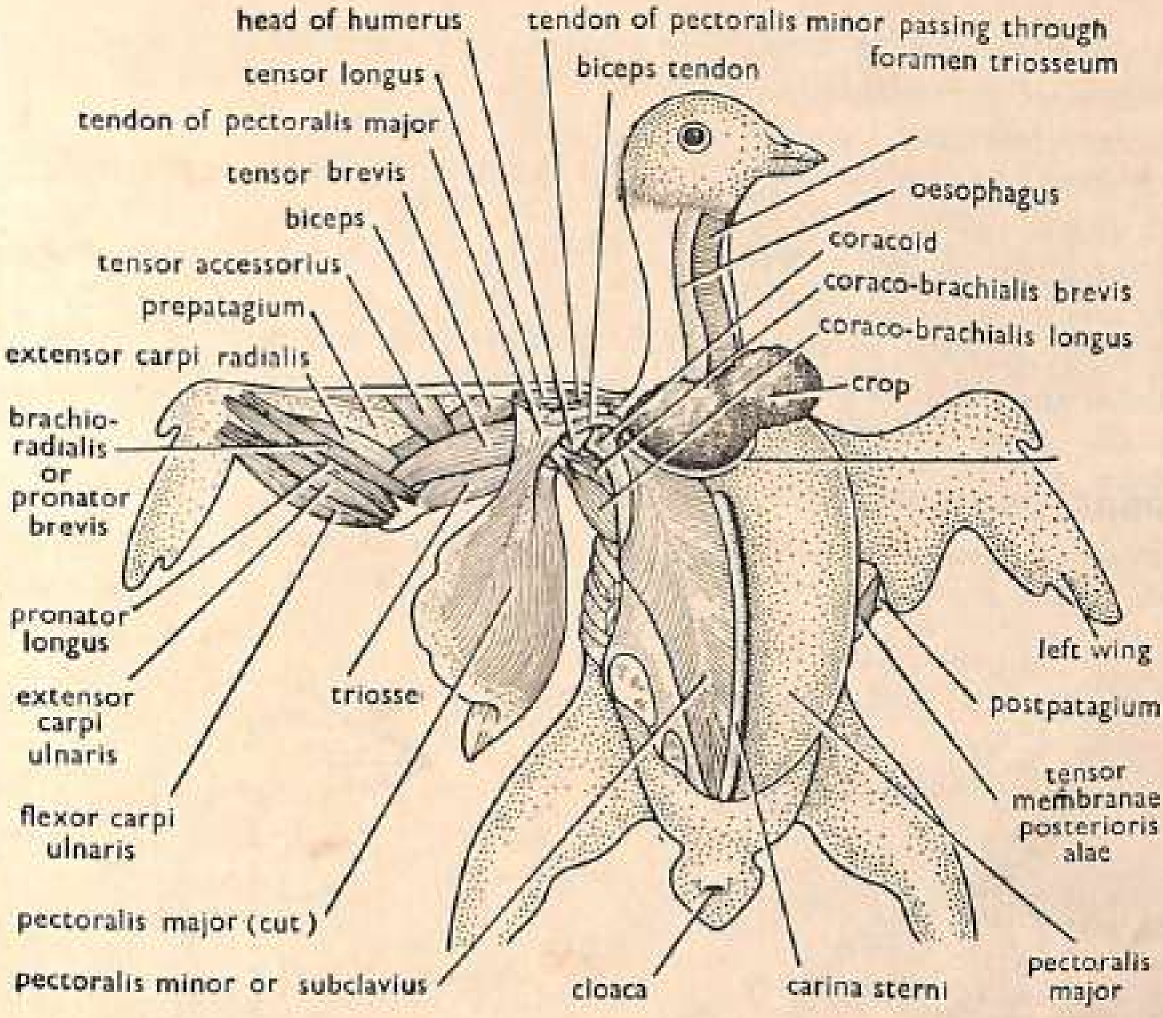


Fig. 7-20. Rock pigeon. Dissection of flight muscles on the right side of the body.

(a) **Cervical air sacs**—Two, found at the base of the neck.

(b) **Interclavicular air sac**—It is a single air sac, found between the two clavicles.

(c) **Anterior thoracic air sacs**—Two in number, covering the ventral surface of the anterior parts of the lungs.

(d) **Posterior thoracic air sacs**—Two in number, lying on the posterior parts of the lungs.

(e) **Abdominal air sacs**—Two in number. These are the largest and found dorsal to intestine.

FLIGHT MUSCLES

Procedure for dissection—*Kill the pigeon by chloroform. Remove the feathers by plucking them. After complete defeathering, lay the pigeon on its back on the dissecting dish. Make a longitudinal incision in the skin from the cloacal aperture up to the lower beak. From the ends of the longitudinal incision cut the skin along the wings and pin up the flaps of skin or remove it by cutting. Also cut through the origin of pectoralis major by the side of keel, the posterior edge of sternum and the clavicle and free it from the underlying muscles. Study the following flight muscles* :

(1) *Pectoralis major*—It originates from whole of the keel from the posterior part of the sternum and clavicle. Its flat tendon is inserted on the deltoid ridge of the humerus. Pectoralis major lowers the wing during flight. Hold the pigeon in your hand, pull the pectoralis major muscle and see how the wing is lowered.

(2) *Pectoralis minor*—It overlaps the pectoralis from the dorsal part of the keel of sternum and the inner part of the ventral surface of the sternum. The *tendon*, formed by its

fibres, passes through the *foramen triosseum* and is inserted on the dorsal surface of the humerus. Pectoralis minor raises the wings.

(3) *Coraco-brachialis longus* and *coraco-brachialis brevis*—They originate from the coracoid and scapula and are inserted on the head of the humerus, to rotate the wings in glenoid cavity.

(4) *Tensor longus, tensor brevis* and *tensor accessorius*—These hold the pre-patagium tensely stretched during flight.

(5) *Tensor posterioris alae*—It keeps the post-patagium tensed.

Other muscles associated with the flight are *flexor carpiulnaris, extensor carpiulnaris, pronator longus, pronator brachioradialis, extensor carpiradialis* and *biceps*.

PERCHING MUSCLES

Note peroneus brevis, peroneus longus, flexors, gastrocnemius, ischioflexorius, ilio-fibualaris, ilio-tibialis and *sartorius, etc.*

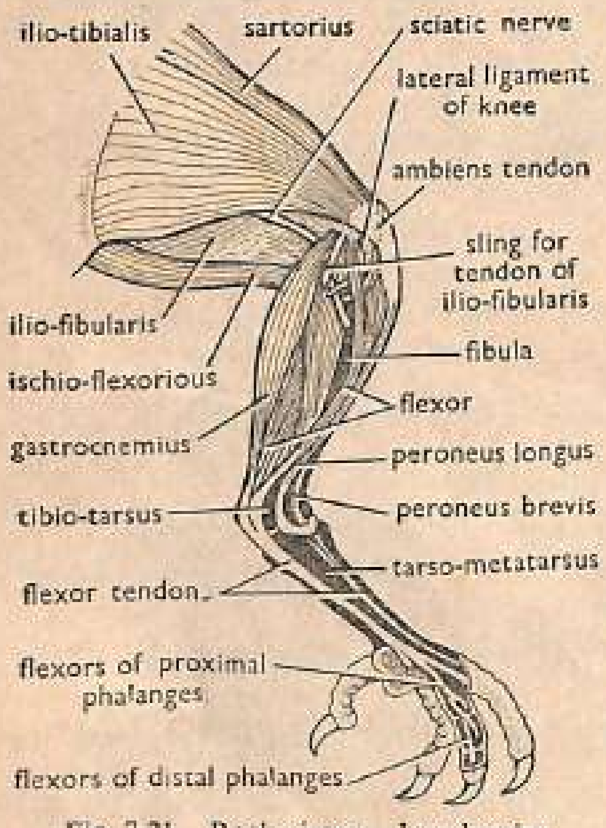


Fig. 7-21. Rock pigeon. Leg showing dissection of perching mechanism.

VENOUS SYSTEM

Procedure—*Remove the pericardium and also cut away the fat and connective tissues at the base of the heart to expose the heart and blood vessels.*

Heart—It is *four-chambered*, consisting of *two auricles* and *two ventricles*.

Veins—The blood from all parts of the body is collected by the following veins :

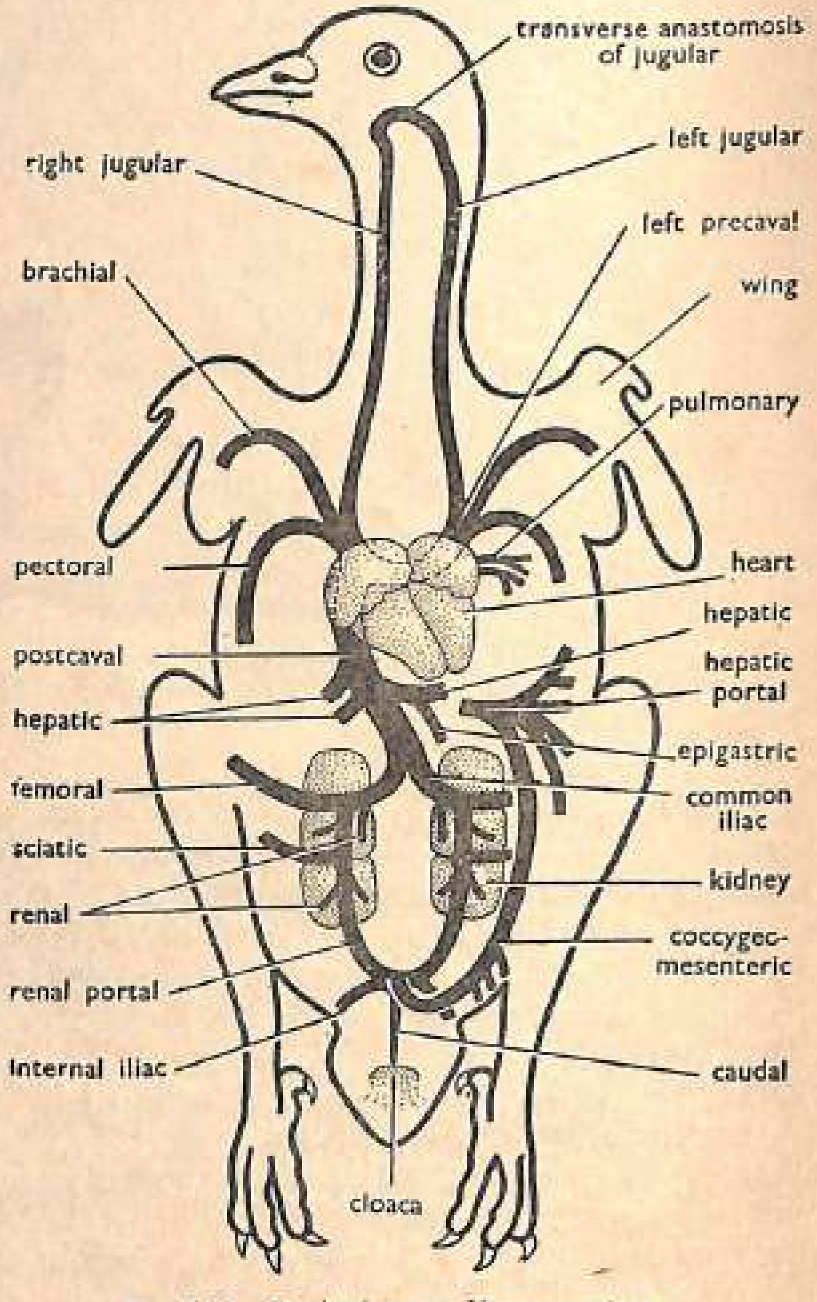


Fig. 7-22. Rock pigeon. Venous system.

(1) *A pair of pulmonary veins*—Two in number. They bring oxygenated blood from the lungs into the left auricle.

(2) *A pair of pre-caval veins*—Each pre-caval is formed by:

(a) **Jugular vein**—Collects blood from the head. The right and left jugular veins unite in the neck by the *inter-jugular transverse anastomosis.*

(b) **Subclavian vein**—It receives a branch, the *brachial*, from the wing and a very large *pectoral vein* from the flight muscles.

(3) *The Post-caval vein*—It collects blood from the posterior part of the body and comprises of the following veins:

(a) **Caudal vein**—Collects blood from the tail.

(b) **Renal portal** or **hypogastric vein**—The caudal vein bifurcates into two renal portal veins, which pass over the kidneys. Each renal portal vein receives—

(i) *Internal iliac*—Collects blood from the pelvic region.

(ii) *Renal veins*—From the kidney.

(iii) *Femoral vein*—From the outer side of the leg.

(iv) *Sciatic vein*—From the inner side of the leg.

(c) **Common iliac vein**—The above veins and renal portal vein on each side unite to form a *common iliac vein.* The common iliac veins of two sides unite together to form the *post-caval vein*, which receives a *hepatic vein* from the liver and enters directly into the right auricle.

(d) **Hepatic portal vein**—It collects blood from the intestine and it also receives a branch from the caudal vein called *coccygeo-mesenteric vein*. The hepatic vein also receives an *epigastric vein* from the peritoneum.

ARTERIAL SYSTEM

The following arteries supply blood to various parts of body. *Conus arteriosus* and ventral aorta divide to form *pulmonary aorta* and *right systemic arch.*

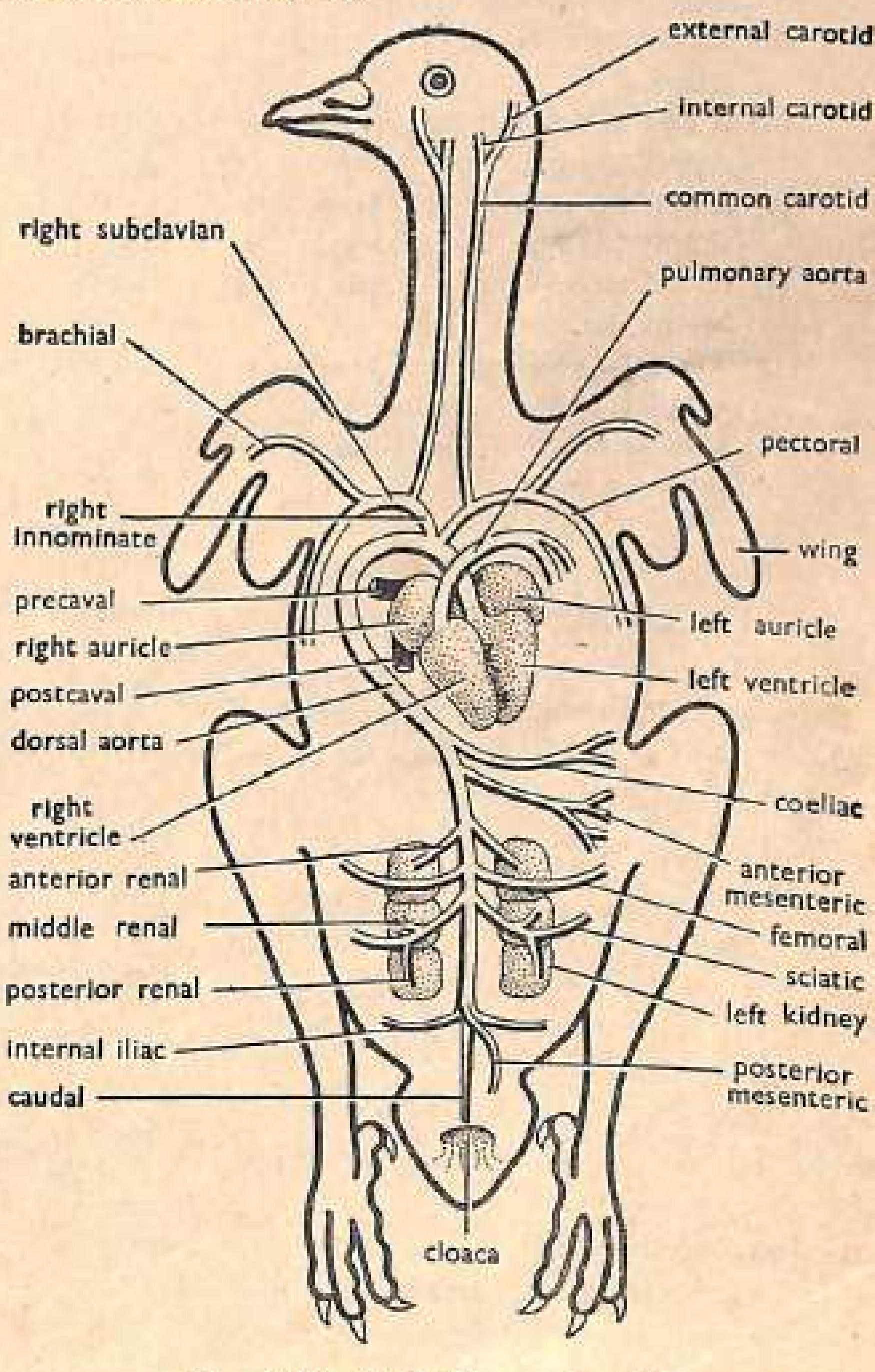


Fig. 7-23. Rock pigeon. Arterial system.

(1) ***Pulmonary arteries***—The pulmonary aorta divides into two pulmonary arteries, which carry deoxygenated blood to lungs, one on each side.

(2) ***Right systemic arch***—In birds only right systemic arch persists in the adult. It originates from the left ventricle and gives several arteries :

(a) **A pair of innominate arteries**—On each side, right systemic arch gives an *innominate artery* which gives two branches—

(i) *Carotid artery*—It extends upwards and divides into *external carotid* and *internal carotid* to supply to the head.

(ii) *Subclavian artery*—It divides into *brachial artery*, which supplies to the wing and *pectoral artery, which* supplies to the pectoral muscles of the flight.

(3) ***Dorsal aorta***—The right systemic arch bends over the heart and continues to posterior end as *dorsal aorta*, giving the following arteries—

(a) **Coeliac artery**—It suplies to stomach and liver.

(b) **Anterior mesenteric artery**—It supplies to small intestine.

(c) **Renal arteries**—They supply to kidneys.

(d) **A pair of femoral arteries**—They supply to outer side of legs.

(e) **A pair of sciatic arteries**—They supply to inner side of legs.

(f) **Iliac arteries**—They supply to the hip region.

(g) **Posterior mesenteric artery**—It supplies to the large intestine.

(h) **Caudal artery**—It supplies to the tail.

RAT (*Rattus rattus*)

EXTERNAL FEATURES

The *rat* is a typical mammal due to the presence of mammary glands and hairs. *Rat* is also a *quadruped* because all the four limbs touch the ground.

For external features first kill the rat with chloroform and then immerse it in a solution of lysol or any antiseptic solution. Lay the rat in a dissecting dish with ventral surface upwards. Note the following structures :

Size—About 25 cm. including tail.

Shape—Body is elongated and brownish in colour.

Divisions—Entire body is regionated into the *head, neck, trunk* and *tail*. The hairs or *pelages* cover and protect the entire body.

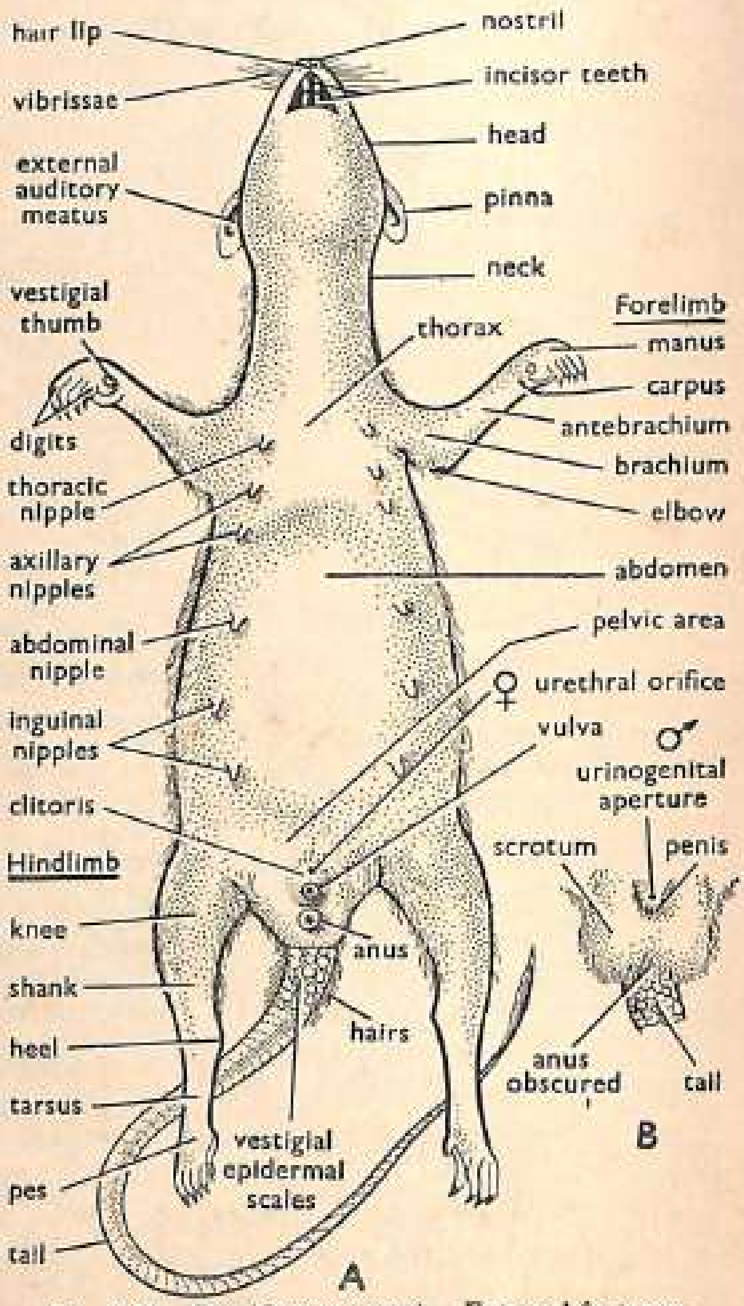


Fig. 7-24 Rat (*Rattus rattus*). External features.
A—Female rat in ventral view.
B—Pelvic region of male rat in ventral view.

Head—The head is elongated and somewhat conical in shape, tapering anteriorly to *terminal nose*. Head has the following structures—

(i) **A pair of nostrils** or **nares**—They are found in front of the nose and lead into the nasal passages. Nostrils can be closed under water.

(ii) **Hair lip**—A cleft is found below the nostrils in upper lip and it exposes the two upper incisors.

(iii) **Mouth**—It is found in a sub-terminal position of the head and leads into the buccal cavity.

(iv) **Teeth**—There are 4 *incisors* and *molars*. Canines and pre-molars are absent. The two front **incisor teeth** are long and they grow throughout the life of rat. These are cutting teeth and form characteristic feature of the order Rodentia to which rat belongs. The incisor teeth are self-sharpening and chisel-like.

(v) Eyes—Two, one on each side. The eyes are small. Each has eyelids and a portion of *cornea* somewhat protrudes through the eyelids to give side vision. The external eyelid has *lacrymal glands*, the secretion of which keeps the eye moist. A *nictitating membrane* is attached to anterior cornea of each eye.

(vi) **External ears** or **pinnae**—These are found on the postero-lateral area of the head.

Neck—It is a short region connecting the head to the body or trunk.

Trunk—It contains *thoracic, abdominal* and *pelvic areas*. In *females*, one pair of thoracic *nipples*, 2 pairs of axillary nipples, one pair of abdominal nipples and 2 pairs of inguinal nipples are seen on ventral surface. The urethral opening, vulval opening and anus lie close together in pelvic region. In *males*, there are two large testes in the *scrotal sacs*.

The trunk region also contains *forelimbs* and *hind limbs*.

Tail—It acts as a balancing organ. At its beginning it contains small overlapping vestigial scales.

GENERAL ANATOMY

Procedure for Dissection

(1) *Kill the rat with chloroform, immerse it in any antiseptic solution and lay it on its back on the dissecting board. Fix the limbs with pin.*

(2) *Make a longitudinal slit in the skin from the pubic symphysis to the tip of the snout and make transverse cuts at the ends of longitudinal cut. Separate the skin from the muscular body wall. They are connected together by loose subcutaneous connective tissue. Note the presence of mammary glands in the female. Make a longitudinal incision in the abdominal wall from the pubic symphysis to xiphisternum, cut parallel to the ribs on both sides and reflect the abdominal wall. Dissect neck region to expose the blood vessels and nerves. Expose and see various glands and organs.*

(1) *Digestive system*—It consists of :

(i) **Mouth**—It leads into the *buccal cavity*, which contains teeth and tongue.

(ii) **Pharynx**—It is a chamber between the mouth and oesophagus. It acts as a common passage for food and air. It channels food into the alimentary canal and air into trachea through glottis.

(iii) **Oesophagus**—It is a short tube, found just below the wind pipe.

(iv) **Stomach**—Oesophagus leads into the stomach, which is pear-shaped and divided into *cardiac* and *pyloric* parts.

(v) **Intestine**—Stomach leads into small intestine, which is divided into *duodenum*, *jejunum* and *ileum*. *Colon* arises from the junction of the small intestine and large intestine. The first part of colon is called as *caecum*, while its terminal end is called as *vermiform appendix*.

(vi) **Rectum**—The large intestine or rectum opens to the exterior by anus.

(2) ***Associated glands***—

(i) **Salivary glands**—Three pairs of these are found in buccal cavity. They secrete saliva.

(ii) **Submaxillary salivary glands**—The largest of three pairs are found on the ventral surface of the neck from the point of the jaw to the manubrium of the sternum. Their ducts open at the base of the incisors.

(iii) **Sublingual salivary glands**—They are found on the sides of the sub-maxillary glands and pour their secretion under the tongue.

(iv) **Parotid salivary glands**—They are found behind and below the bases of the ears on ventro-lateral surface of the neck.

(v) **Thymus and thyroid glands**—These are endocrine glands.

(vi) **Liver**—It is composed of four lobes.

(vii) **Pancreas**—It is also an endocrine gland, suspended by delicate mesenteries between the stomach and the duodenum.

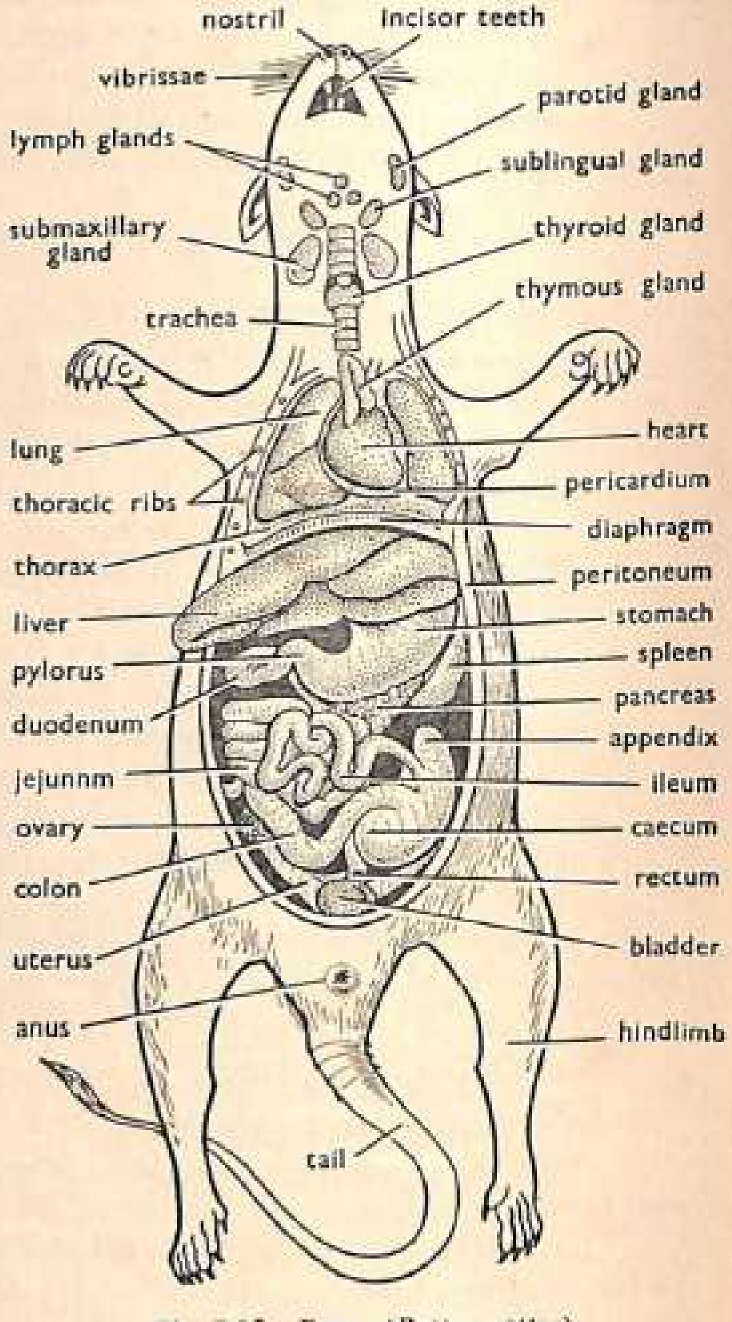


Fig. 7-25. Rat. (*Rattus rattus*). Dissection of general anatomy.

(3) ***Heart***—It lies in pericardium and is composed of 2 auricles and 2 ventricles.

VENOUS SYSTEM

The blood from the entire body is collected by the following veins :

1. *A pair of pulmonary veins*—They carry oxygenated blood from lungs to the left auricle.
2. *A pair of pre-caval veins*—These collect blood from the anterior body. Each pre-caval comprises of :

   (i) *Jugular vein*—It divides into two :

   (a) **External jugular**—It collects blood from lower jaw.

   (b) **Internal jugular**—It collects blood from the brain. It joins with external jugular.

   (ii) *Subclavian vein*—It collects blood from the forelimb and opens into the pre-caval vein.

(iii) *Anterior intercostal vein*—It collects blood from the intercostal spaces and opens into the pre-caval vein.

(iv) *Internal mammary vein*—It collects blood from the inner surface of the ventral thoracic wall.

(v) *Phrenic vein*—It collects blood from the diaphragm.

3. *Post-caval vein*—It collects blood from the posterior part of the body by the following veins :

(i) *Caudal vein*—It collects blood from the tail.

(ii) *A pair of iliac veins*—Each iliac vein divides into *femoral vein* which collects blood from the outer side of the leg and *sciatic vein* which collects blood from the inner side of the leg. The two iliac veins join with the post-caval.

(iii) *A pair of ilio-lumbar veins*—They collect blood from the lumbar region.

(iv) *Posterior mesenteric vein*—It collects blood from the large intestine.

(v) *A pair of genital veins*—They collect blood from gonads.

(vi) *Anterior mesenteric vein*—It collects blood from the anterior gut.

4. *Hepatic portal vein*—It comprises of the following veins :

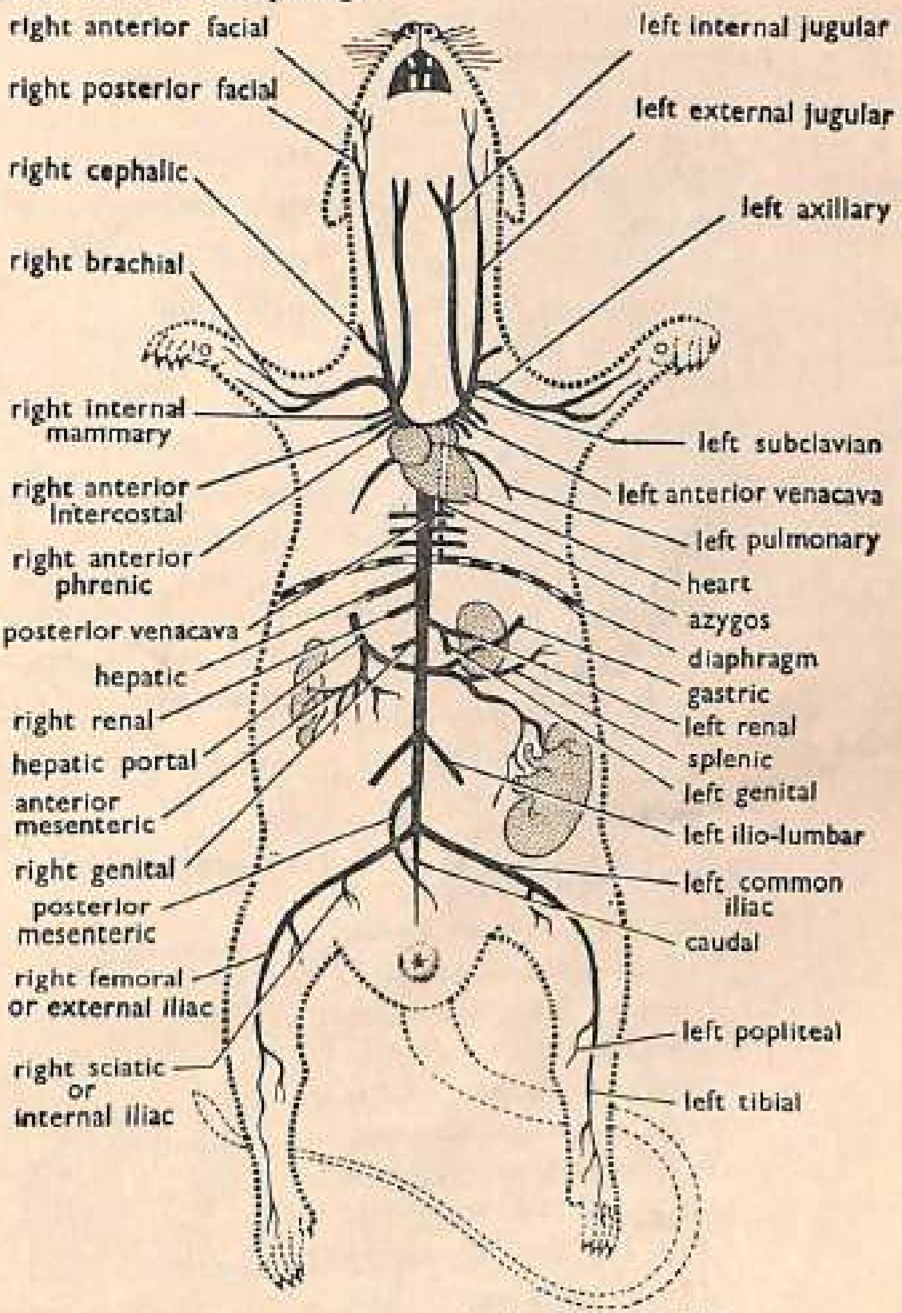


Fig. 7-26. Rat (*Rattus rattus*). Venous system.

(i) *Gastric vein*—It collects blood from the stomach.

(ii) *Anterior mesenteric*—It collects blood from the ileum.

(iii) *Splenic*—It collects blood from the spleen.

(iv) *Posterior mesenteric*—It collects blood from the large intestine.

The hepatic portal vein opens into the liver.

ARTERIAL SYSTEM

Arteries distribute blood to various parts of the body.

First locate the origin of the systemic aorta. It originates from the left ventricle, passes dorsal to the pulmonary arch and curves round to the dorsal side of the heart and lies ventral to the vertebral column, where it extends backwards as dorsal aorta. The systemic arch distributes blood to the anterior region, while the dorsal aorta to the posterior region.

The arteries are :

(1) *Pulmonary arteries*—They carry de-oxygenated blood to lungs. The pulmonary arteries are given by pulmonary aorta, which originates from the right ventricle and curves over on to the dorsal side of the heart.

(2) *Systemic aorta*—It gives the following branches :

(i) *Innominate artery* — It divides into right *subclavian* and right *carotid* arteries. The right *subclavian artery* further branches into right cervical artery, right brachial artery, right axillary artery, right vertebral artery, right radial artery and the right internal mammary artery.

(ii) The *left subclavian* artery arises directly from the systemic arch and supplies to shoulder girdle and arms. Its branches correspond to the right subclavian.

(iii) The *right carotid artery* proceeds forwards along the trachea and near the angle of jaws it divides into the *internal carotid* supplying to the brain, and the *external carotid*, supplying the right side of the head and face. The *left carotid* artery directly originates from the systemic arch and has internal and external branches.

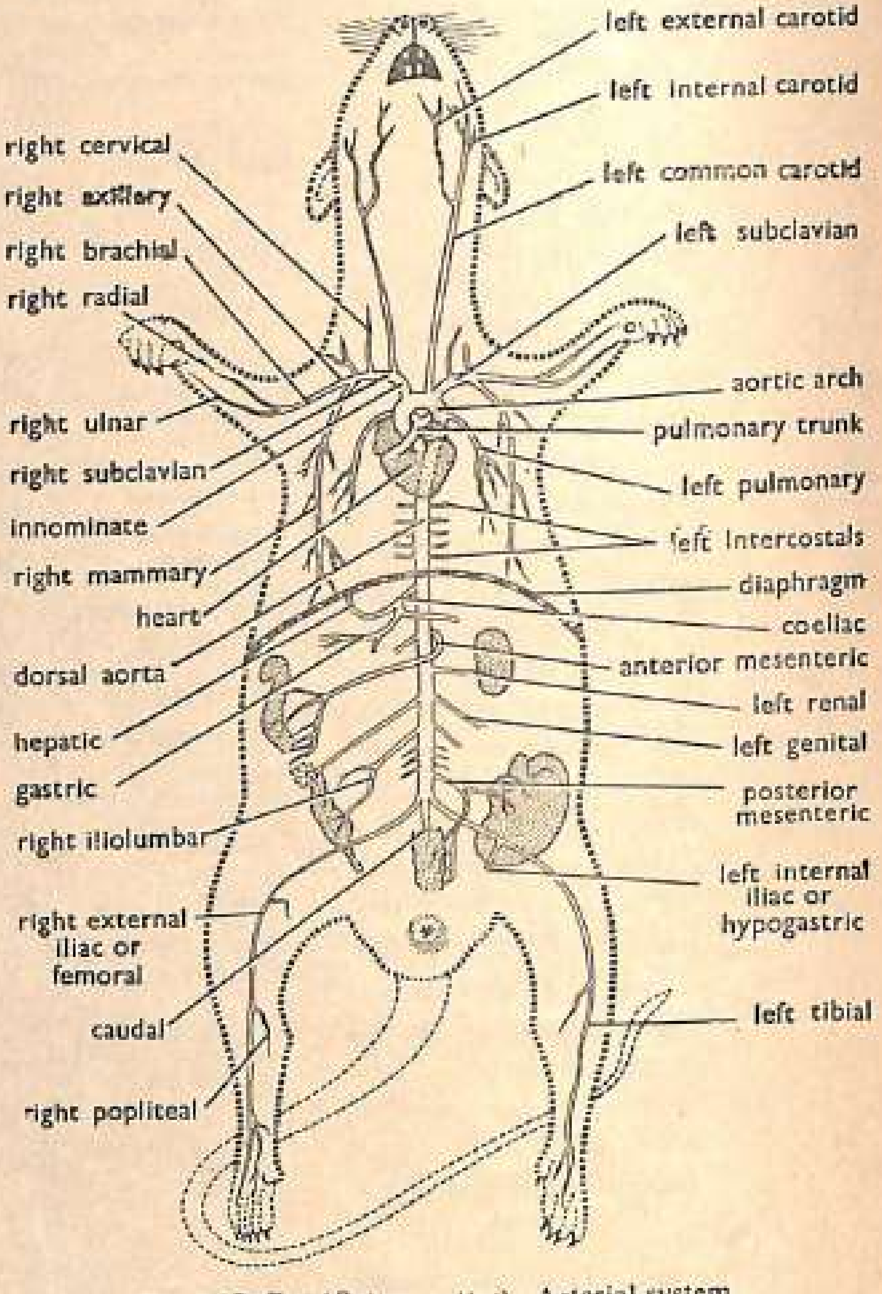


Fig. 7-27. Rat (*Rattus rattus*). Arterial system.

(3) *Dorsal aorta*—It comprises of the following arteries :

(i) *Intercostal arteries*—They are in several pairs supplying to the wall of the chest.

(ii) *Coeliac artery*—It gives two branches. The *hepatic artery* supplies to the liver and the *lienogastric artery* supplies to the stomach and spleen.

(iii) *Anterior mesenteric artery*—It supplies to the intestine.

(iv) *Two gonadial arteries* supply to gonads.

(v) *A pair of renal arteries* supply to two kidneys.

(vi) *Posterior mesenteric artery*—It supplies to the rectum.

(vii) *A pair of ilio-lumbar arteries*—They supply to the body wall.

(viii) *A pair of common iliac arteries*—On each side, each common iliac originates in the pelvic region and divides into *internal iliac* and *external iliac*, which supply to the legs, and *vesicle artery* supplying to the urinary bladder.

(ix) *Caudal artery*—The dorsal aorta continues into tail as caudal artery.

MALE URINOGENITAL SYSTEM

Procedure—*For urinogenital system cut the sides of the pubic symphysis and remove the cut portion so as to expose the posterior part of the urinogenital system. This system comprises of urinary and genital organs.*

1. *Urinary organs* or *Kidneys*—You have already noted the position of **kidneys** which are surrounded by fat. The point of attachment of kidney with ureter is called as ***hilus***. Also observe and trace the ureter up to the urinary bladder.

Remove one kidney and observe the **hilus**, *through which the ureter and blood vessels enter and leave. With the help of a sharp scalpel cut open the kidney longitudinally and note the following parts* :

The substance of the kidney is differentiated into an outer *cortex* and inner *medulla*. The cortex is highly vascular and has a dotted appearance due to the presence of *Malpighian bodies*, which consist of Bowman's capsules enclosing glomeruli. The Malpighian bodies are the terminations of uriniferous tubules, which have coiled and looped course. The medulla is striated and contains the non-glandular parts of the urinary tubules. The inner surface of the medulla projects into the pelvis of the kidney forming the pyramid, on which the tubules of the kidney open.

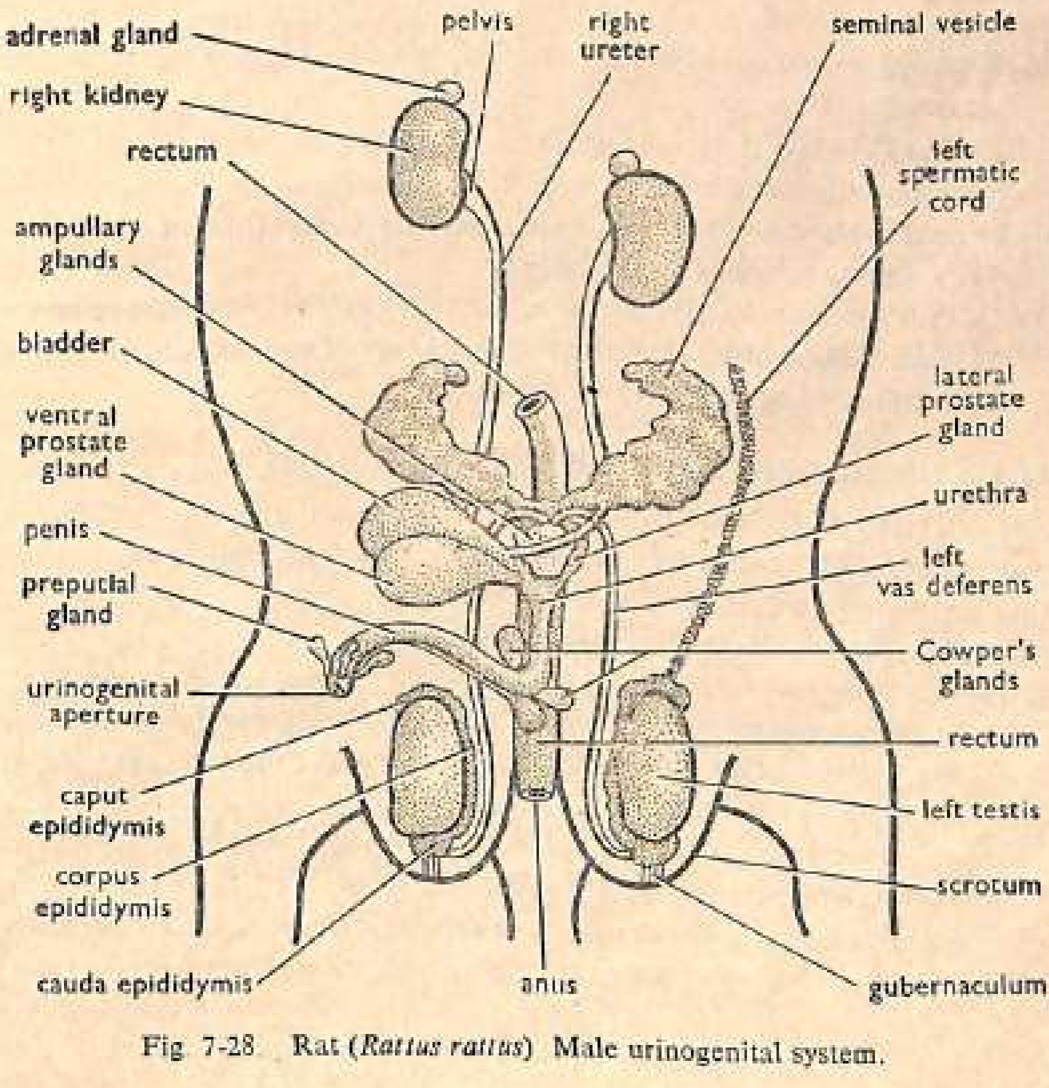


Fig 7-28 Rat (*Rattus rattus*) Male urinogenital system.

2. *Genital organs*—Note the following parts :
   (i) *Testes*—A pair of testes is found in the *scrotal sacs*. The scrotal sacs are a pair of pouches in front of the anus and between the hind legs. The testis can be exposed by cutting the scrotal sacs. Each testis is elongated and ovoid body attached to the hinder end of the scrotal sac by a band of tissues called *gubernaculum*. *In the very infant rat the testes lie in the abdomen close to the kidneys and just before maturity, they descend into the scrotal sacs along the inguinal canals*.
   (ii) *Epididymis*—It is an irregular and convoluted tube, found along the inner edge of testis. At anterior end it forms *caput epididymis* and at posterior end *cauda epididymis*. Cauda epididymis gives rise to vas deferens.
   (iii) *Vas deferens*—Each vas deferens coils round the ureter from the outside before opening into the urethra behind the urinary bladder.
   (iv) *Urethra*—It is the common duct for urine and sperms opening into the penis.
   (v) *Penis*—It is copulatory organ through which sperms are discharged into the female genital organ or vagina of the female. The urethra opens at the tip of the penis by a slit-like opening. The tip of the penis is covered by loose skin called *prepuce*.
   (vi) *Spermatic cord*—It is an elongated cord-like structure made up by connective tissue, blood vessels and nerves, which originate from the caput epididymis and running to the body cavity through inguinal canal.
   (vii) *Accessory glands*—The following glands are associated with male genital system—
      (a) *Ampullar glands*—The outer end of the vas deferens near the entrance into the urethra is enlarged into the ampulla, which contains ampullar glands to secrete mucus.
      (b) *Vesicular glands*—They are branched glands originating from the vas deferens behind the ampulla.
      (c) *Prostate gland*—It is a large and lobulated gland, situated just behind the junction of urinary bladder with the vasa deferentia.
      (d) *Preputial glands*—They originate from the inner fold of skin forming prepuce. They secrete odorous secretion.
      (e) *Cowper's glands*—They originate from the urethra at the base of the penis. They produce mucous secretion during sexual excitement and also protect the sperms from traces of acids found in urethra.

FEMALE URINOGENITAL SYSTEM

1. **Urinary system**—It consists of kidneys, ureters and urinary bladder, which are like those of male. The *urethra* is an elongated tube running towards the posterior side, opening separately at the tip of the *clitoris*.
2. **Reproductive system**—It has the following parts :
   (i) *Ovaries*—They are a pair of small yellowish, compact structures like pea on outer sides of the kidneys and are suspended in the body cavity by *mesovarium*.
   (ii) *Fallopian tubes*—They are coiled and convoluted tubes. Their anterior ends form *oviducal funnels*.
   (iii) *Uteri*—The posterior ends of the fallopian tubes become thickened to form uteri.
   (iv) *Vagina*—It is a common chamber formed by the union of the two uteri. It serves as copulatory chamber. It opens to the exterior by a slit-like opening called *vulva*
   (v) *Clitoris*—It is a rod-like structure, found anterior to vulva.

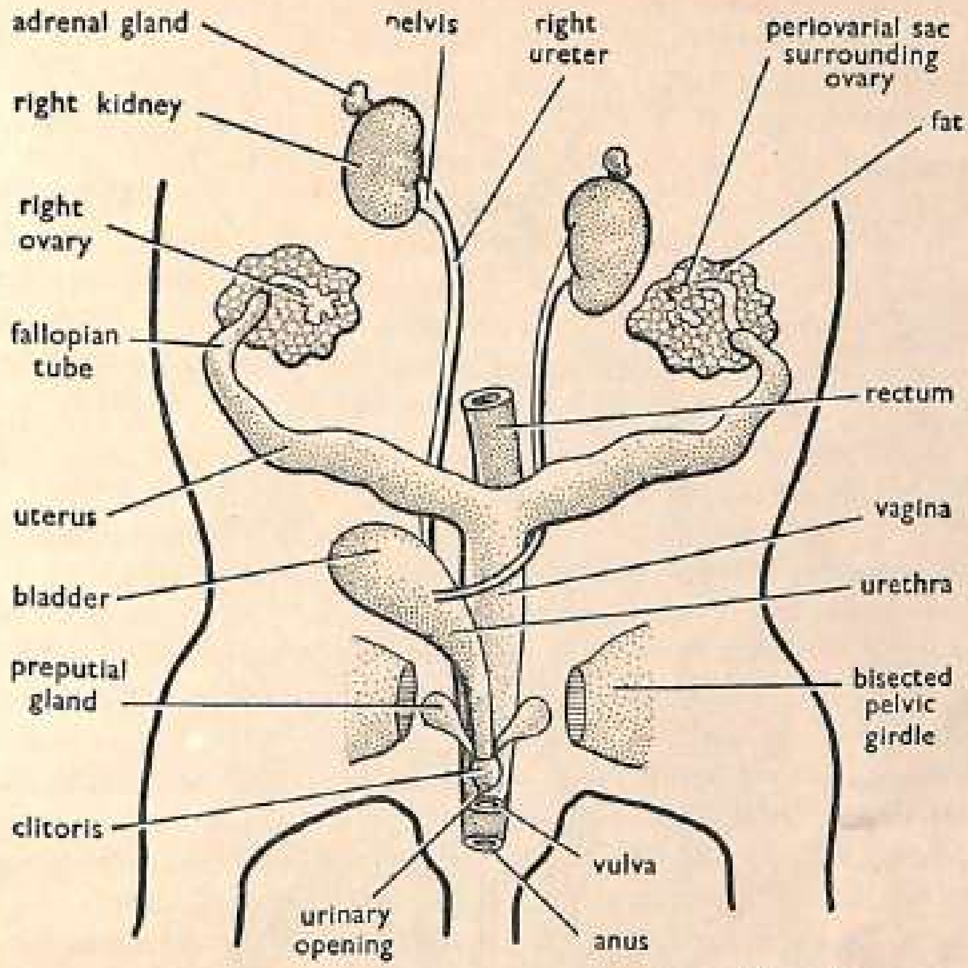


Fig. 7-29. Rat (*Rattus rattus*). Female urinogenital system.

(vi) *Accessory glands*—They are found only in the uterus consisting of.

(a) *Uterine* and *vestibular* glands.

(b) *Bartholi's glands*—These correspond with Cowper's glands of male and are related to urinogenital passage.

(c) *Preputial glands*—These are large glands opening near the tip of clitoris.

DISSECTION OF THE MUSCLES. BLOOD VESSELS AND NERVES OF THE NECK REGION

(A) Muscles

Remove the skin of the neck and note the following muscles :

(1) **Digastric muscles.** (2) **Sternohyoid muscles**—Hyoid to manubrium.

(3) **Omohyoid muscles.** (4) **Masseter muscles.**

(5) **Sternomastoid muscles**—Manubrium to skull.

(6) **Cleidomastoid muscles**—Clavicle to skull.

(7) **Clavotrapzius muscles**—Clavicle to skull.

(8) **Deltoid muscle**—Scapula to humerus.

(B) Blood Vessels and Trachea

For dissecting the neck region expose the hyoid. Remove hyoid only when dissection of the neck region is completed.

1. **Common carotid arteries**—They lie along the trachea. Note their divisions into the *external* and *internal carotid arteries*.

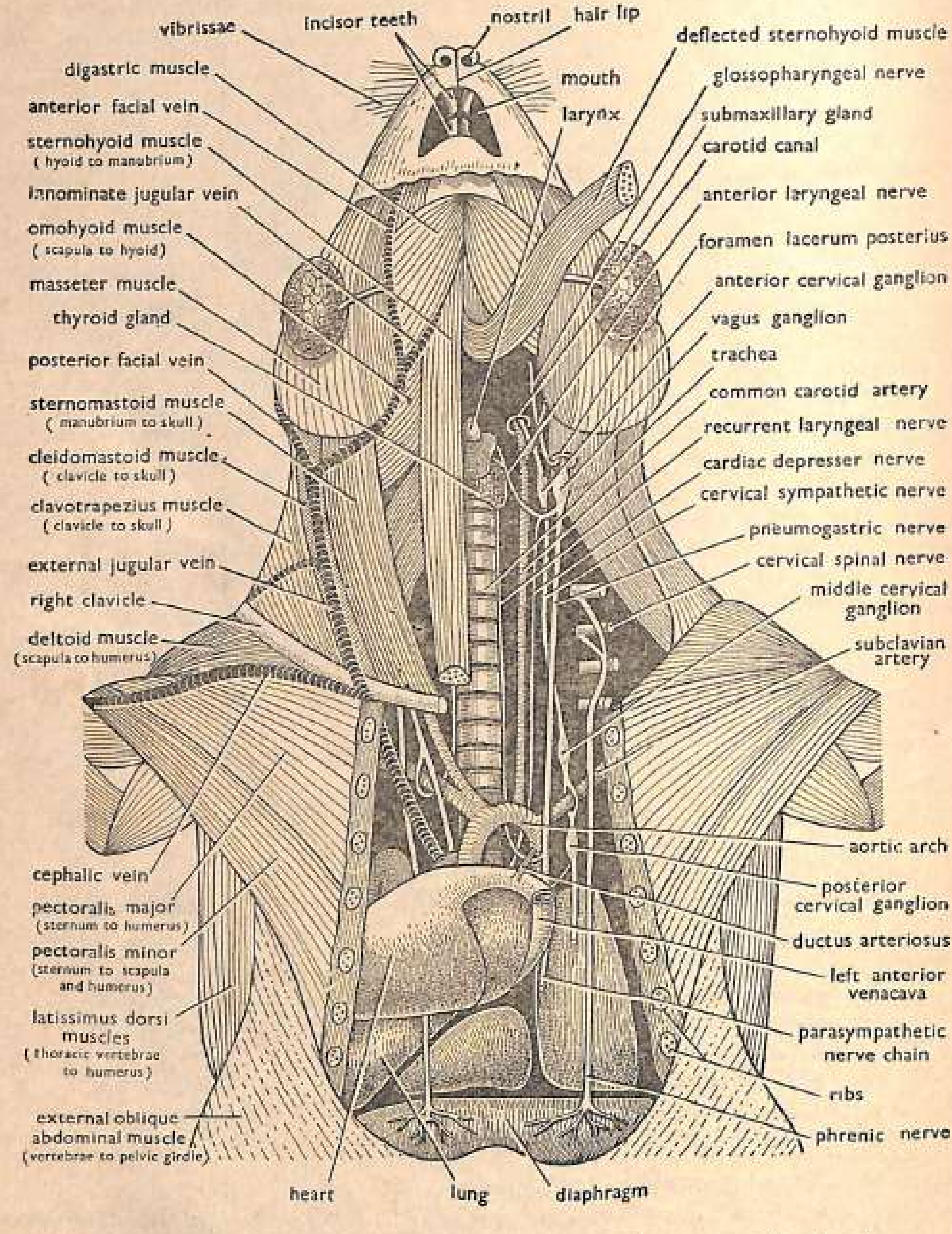


Fig. 7–30. Rat (*Rattus rattus*). Dissection of muscles, blood vessels nerves and of neck region.

2. **Jugular veins**—The *external* and *internal jugular veins*, collecting blood from skull and brain, unite with *cephalic* and *subclavian* veins to form the pre-caval.
3. **Trachea**—It connects glottis with lungs. Anteriorly, trachea is dilated into the larynx, whose walls are supported by **thyroid**, **arytenoid** and **cricoid** cartilages. Note **thyroid** gland on either side of the larynx.

C. Neck Nerves

Trace the carotid artery carefully and note the nerves lying by its side. Expose the pneumogastric nerves running on outer side.

1. **Vagus nerve**—The *vagus* or *pneumogastric* is a stout nerve containing a ganglionic swelling at its origin. It runs downwards from the foramen lacerum posterius and extends backwards along with carotid artery in the neck region.
2. **Anterior laryngeal nerve**—It is a fine delicate nerve originating from the pneumogastric nerve from the upper border of the thyroid cartilages. It innervates the mucous membrane of the larynx.
3. **Depressor nerve**—It is a slender nerve originating from the anterior laryngeal nerve. It extends backwards along the neck dorsal to the carotid artery and it innervates heart.
4. **Posterior laryngeal or recurrent laryngeal**—It originates from the pneumogastric nerve or vagus nerve just above the heart and it extends forwards along the side of the trachea.
5. **Cervical sympathetic nerve**—It is a slender nerve running between the vagus and depressor nerves. It swells into ganglia both anteriorly into *anterior cervical ganglion* and posteriorly into the *middle* and *posterior cervical ganglia.*
6. **Phrenic nerve**—It orignates from the fourth cervical nerve and it extends backwards along the vertebral column. After passing through the thorax, phrenic nerve gives several small branches in the diaphragm.

Chapter **8**

Experimental Physiology

(Colour, Precipitation and Enzyme Reactions of Foodstuffs)

Colour and precipitation reactions of **carbohydrates, fats and proteins.** These chemical compounds include important foodstuffs and the following chemicals and glass apparatuses are required for their biochemical analysis :

A. CHEMICALS

1. Ether.
2. Chloroform.
3. Absolute alcohol.
4. Olive oil.
5. Sodium hydrogen sulphate.
6. Potassium hydrogen sulphate.
7. Oleic acid.
8. Caustic soda.
9. Alcoholic caustic soda.
10. Conc. HCl (hydrochloric acid).
11. Conc. H_2SO_4 (sulphuric acid).
12. Sodium chloride.
13. Calcium chloride.
14. Methylene blue 1 per cent.
15. NaOH saturated.
16. Potassium ferricyanide solution 1 per cent.
17. Copper sulphate 0.5 per cent.
18. Copper sulphate 1.0 per cent.
19. Fehling's solution.
20. Benedict's solution.
21. Picric acid saturated solution.
22. Nylander's reagent.
23. Barfoed's reagent.
24. NaOH 40 per cent.
25. Glucose 1 per cent.
26. Glucose 2 per cent.
27. Phenylhydrazine hydrochloride.
28. Sodium acetate.
29. Acetic acid glacial.
30. α-naphthol 1 per cent.
31. Seliwanoff's reagent.
32. Ethyl acetate.
33. Glucose 0·2 per cent.
34. Glucose 0.5 per cent.
35. Fructose 0.2 per cent.
36. Fructose 0.5 per cent.
37. Lactose 2 per cent.
38. Maltose 2 per cent.
39. Sucrose 2 per cent.
40. Iodine solution.
41. Ammonium sulphate.
42. Tannic acid.
43. Egg white 5 per cent.
44. Mercuric chloride ($HgCl_2$) saturated.
45. Ferric chloride 0.5–1.0 per cent.
46. Lead acetate.
47. Silver nitrate $AgNO_3$.
48. Barium chloride $BaCl_2$.
49. Sulphosalicylic acid 20 per cent.
50. Esbach's reagent.
51. Potassium ferrocyanide solution.
52. Mercuric sulphate.
53. Sodium nitrite $NaNO_2$.
54. Glyoxalic acid reagent.
55. Sodium hypobromide (NaOBr).
56. Ninhydrin 1 per cent.
57. Chlorophenol red.
58. Peptone.
59. Mercuric nitrate.
60. Glycerol.
61. Magnesium sulphate.
62. Phenolphthalein.
63. Potassium dihydrogen phosphate.
64. Na–K–tartarate (Rochelle salt).
65. Bismuth sub-nitrate.
66. Thymol alcoholic 5 per cent.

Some Important Laboratory Reagents

1. **Alpha naphthol**—Dissolve 1 gram of α–naphthol in 95 per cent alcohol.
2. **Ammonium molybdate**—Dissolve 75 grams of ammonium molybdate crystals in 300 cc of strong ammonia. Add this solution in 900 cc of conc. HNO_3 and then add 400 cc of water, cool and add more 1600 cc of water. Filter.
3. **Barfoed's reagent**—Dissolve 13·3 grams of neutral copper acetate crystals in 200 cc of distilled water. Filter and add 1·8 cc of glacial acetic acid.
4. **Barium chloride**—10 per cent solution in water.
5. **Basic lead acetate**—Dissolve 180 grams of lead acetate in 700 cc of water.
6. **Benedict's reagent** (Qualitative)—Prepare solutions A and B.
   A. Dissolve by heating 173 grams of sodium citrate and 100 grams of anhydrous sodium carbonate in about 800 cc of water.
   B. Dissolve 17·3 grams of copper sulphate crystals in 100 cc of water. Cool the solutions. Add B to A with constant stirring in 1000 cc titration flask and dilute with distilled water up to the mark.
7. **Chromic acid** (for cleaning glass apparatus)—Dissolve 60 grams of potassium dichromate in 300 cc of water in a glass trough and then add 460 cc of conc. H_2SO_4. The mixture becomes very hot. Cool under running water. The liquid is utilized to clean the glass apparatus.
8. **Esbach's reagent**—Dissolve 1 gram of picric acid and 2 grams of citric acid in 100 cc titration flask. Dilute with water up to the mark.
9. **Fehling's solution**—(A) Dissolve 7·93 grams of copper sulphate crystals in 100 cc of distilled water. (B) Dissolve 250 grams of KOH and 320 grams of Na–K–tartarate in 1000 cc of distilled water.
10. **Nylander's reagent**—Dissolve 2 grams of bismuth sub-nitrate and 4 grams of Na–K–tartarate in 100 cc of 10 per cent KOH. Cool and filter.

B. GLASS APPARATUS

Test tubes, funnels, beakers, pipettes, measuring cylinders, glass-stoppered bottles, spirit lamps, titration flasks, conical flasks, reagent bottles. Besides these, filter papers, cotton, test tube holders, test tube stands are also required.

Note—All the glass apparatus must be chemically and physiologically cleaned. For example, a test tube should be washed first with vim and then it should be dried. After removing moisture, rinse the tube with chromic acid solution. Then wash the test tube 9 times with tap water and 3 times with distilled water. Now, the test tube is cleaned properly and is ready for physiological experiments.

I. CARBOHYDRATES

Carbohydrates are abundantly distributed in the plants and to a small extent in the animals. In animals they are found in free state or in combination with proteins. The name carbohydrate is given because they are composed of carbon, hydrogen and oxygen atoms. H_2 and O_2 are found in the same proportion as in water (H_2O). Chemically carbohydrates are aldehyde and ketone derivatives of alcohols (aldoses and ketoses). In general, carbohydrates are white solids, sparingly soluble in organic liquids, except for certain polysaccharides, soluble in water. Many carbohydrates are of low molecular weight and having sweet taste. Carbohydrates are classified into 3 groups :

(1) **Monosaccharides** or simple sugars ($C_6H_{12}O_6$).

(2) **Di- and tri-saccharides** or compound sugars. (3) **Polysaccharides.**

MONOSACCHARIDES

Monosaccharides or simple sugars occur abundantly in nature in the form of **glucose and fructose.** They occur in white crystalline form, easily soluble in water and hot alcohol and practically insoluble in organic solvents like absolute alcohol, ether and acetone, etc. They are optically active and being aldehydes and ketones show common reactions.

In alkaline solution all the monosaccharides and many disaccharides behave as reducing agents and are easily oxidised by various reagents as silver and copper, etc. Most of the quantitative analyses for sugars depend upon the measurement of the reduction of Cu^{++} to Cu^{+} by alkaline sugar solutions.

Experiments with Glucose and Fructose

Make 0·2 per cent and 2 per cent solutions of the Dextrose–D or Fructose and perform the following experiments in order to identify the reducing action of glucose and fructose :

Experiment No. 1

(a) *Procedure*—In a test tube take 3 cc of distilled water, then add a drop of methylene blue (1%) and then add 0·5 cc of 40 per cent NaOH. **Boil** the solution. Colour is not discharged; blue colour remains. Add 1 cc of 0·2 per cent glucose or fructose solution and boil.

(b) *Result*—The solution is decolourised due to the formation of leuco-methylene blue, the reduction product of methylene blue.

Experiment No. 2. Reduction of alkaline ferricyanide

(a) *Procedure*—In a test tube take 3 cc of 1 per cent potassium ferricyanide solution and add 1 cc of 40 per cent NaOH solution. Boil the solution. Add 0·2 per cent glucose solution to the hot solution drop by drop and keep on boiling.

(b) *Result*—The yellow colour of the ferricyanide begins to fade and finally decolourises.

Experiment No. 3. Tommer's Test—Reduction of alkaline copper sulphate

(a) *Procedure*—In a test tube take 2 cc of 0·5 per cent copper sulphate solution, then and 2 cc of 0.2 per cent glucose solution and mix. Add 2 cc of 40 per cent NaOH solution. A clear blue solution is obtained. Glucose acts as a solvent for cupric hydroxide $Cu(OH)_2$ and prevents its precipitation. Boil.

(b) *Result*—Yellow or red precipitate of Cu_2O is formed due to the reduction of $CuSO_4$.

$$2Cu\,(OH)_2 - O \rightarrow Cu_2O + 2H_2O$$

Experiment No. 4. Fehling's Test

(a) *Procedure*—Take 5 cc of Fehling's solution and boil. There is no change of colour on the formation of precipitate. (In case of colour change and precipitate formation reject the solution.) Add 1 cc of glucose solution and boil again.

(b) *Result*—Colour changes with the formation of yellow or brick-red precipitate of Cu_2O.

Experiment No. 5. Benedict's Test

(a) *Procedure*—In a test tube take 5 cc of Benedict's reagent, then add 0·5 cc of glucose solution and heat to boiling. Boil for 2 minutes. Cool the solution under tap water.

(b) *Result*—Green, yellow or red precipitate of Cu_2O is formed.

Experiment No. 6. Picric Acid Test

(a) *Procedure*—In a test tube take 3 cc of 2 per cent glucose solution, then add 1 cc of picric acid saturated solution and then add 1 cc of 40 per cent NaOH.

(b) *Result*—Picric acid is reduced to picramic acid with the formation of red colour.

$$C_6H_2OH(NO_2)_3 + 3H_2 \rightarrow C_6H_2OH.\ NH_2(NO_2)_2 + 2H_2O$$

Experiment No. 7. Nylander's Test

(a) *Procedure*—In a test tube take 5 cc of 2 per cent glucose solution, add 0·5 cc of Nylander's reagent and heat to boiling and keep on boiling for 2 minutes.

(b) *Result*—The solution becomes dark black, as bismuth sub-nitrate is reduced to bismuth.

$$Bi(OH)_2NO_3 + KOH \rightarrow Bi(OH)_3 + KNO_3$$
$$2Bi(OH)_3 + 3O \rightarrow 2Bi + 3H_2O$$

Experiment No. 8. Rapid Furfural Test

(a) *Procedure*—Take 1 cc. of 2 per cent fructose solution, add 6 drops of α–naphthol, then add 5 cc of conc. HCl in a test tube Boil.

(b) *Result*—As the mixture begins to boil, deep purple colour develops.

DISACCHARIDES

Disaccharides include **lactose, maltose** and **sucrose.**

(1) **Lactose** is found in milk and also in the urine of women during pregnancy and lactation.

(2) **Maltose**—It is the final product of starch hydrolysis.

(3) **Sucrose**—Abundant in plants as a reserve food material.

Lactose and **maltose** are reducing sugars and give positive Tommer's, Fehling's, Benedict's and Barfoed's tests. Sucrose gives positive Rapid. Furfural and Seliwanoff's tests. Lactose and maltose form **osazones** with characteristic crystalline forms and they can be classified by microscopic examination. **Lactosazone** forms mushroom-shaped crystals, **glucosazone** forms needle-shaped crystals, while **maltosazone** forms flower-shaped crystals. Sucrose does not form osazone. For the osazone formation, prepare 0.5 per cent glucose and fructose solutions, 2 per cent lactose, 2 per cent maltose and 2 per cent sucrose. In a test tube take 5 cc of sugar solution and add 10 drops of glacial acetic acid, then add a knife point of phenyl-hydrazine hydrochloride, then add twice the amount of sodium acetate crystals, give a little heat to the solution to dissolve the solids. Filter the solution and keep the filtrate in boiling water bath for 20 minutes, then remove and examine.

II. PROTEINS

Proteins, found in animals and plants, are important building blocks formed by amino acids, condensed together by peptide linkage. All proteins contain carbon, hydrogen, oxygen, nitrogen and with a few exceptions sulphur also. The elementary composition of proteins consists of approximately C=45–55 per cent, H=6–8 per cent, O=19–25 per cent and N=14–20 per cent. Proteins have high molecular weight. They contain free amino and carboxyl groups and so they can combine with bases and acids depending upon the pH of the medium. On hydrolysis, proteins break into peptones, proteoses, peptides and amino acids. Chemical behaviour of the proteins is due to the amino acids in the protein molecules.

For experiments fresh 5 per cent solution of egg white is prepared. The egg white is filtered through cotton. Dissolve 5 cc of egg white into 95 cc of distilled water for 5 per cent egg white solution. Proteins show both precipitation and colour reactions.

(A) Precipitation of Proteins with Heavy Metals

Experiment No. 1

(a) *Procedure*—In a test tube take 3 cc of 5 per cent egg white solution, then add mercuric chloride drop by drop.

(b) *Result*—White turbidity is produced first which becomes thick and granular. The heavy metal salts precipitate protein solutions. This precipitate is generally soluble in excess of the salt solutions.

Experiment No. 2

(a) *Procedure*—Take 3 cc of 5 per cent egg white solution and add 0·5 per cent ferric chloride solution drop by drop.

(b) *Result*—On addition of first drop, turbidity appears and it increases on addition of subsequent drops. If $FeCl_3$ is added in excess, the turbidity disappears.

(B) Precipitation of Proteins by Alkaloid Reagents

Experiment No. 3

(a) *Procedure*—In a test tube take 3 cc of 5 per cent egg white solution and add 20 per cent sulphosalicylic acid.

(b) *Result*—White precipitate is obtained.

Experiment No. 4. Esbach's Test

(a) *Procedure*—Take 3 cc of 5 per cent egg white solution in a test tube and add Esbach's reagent.

(b) *Result*—Yellowish precipitate is formed. By this method the quantity of albumen in urine is also estimated.

Experiment No. 5. Tannic Acid Test

(a) *Procedure*—In a test tube, take 3 cc of 5 per cent egg white solution and then add 5 drops of freshly-prepared tannic acid solution.

(b) *Result*—Brownish and non-granular precipitate is formed.

Experiment No. 6. Heller's Test

(a) *Procedure*—Take 3 cc of concentrated HNO_3 in a test tube and then add very carefully 3 cc of 5 per cent egg white solution by means of a pipette in such a manner that it forms upper layer. Mix gradually by rotating between palms.

(b) *Result*—A white ring is formed at the junction of the two solutions.

Experiment No. 7. Acetic Acid–Potassium Ferrocyanide Test

(a) *Procedure*—In a test tube take 3 cc of 5 per cent egg white solution, then add 3 drops of glacial acetic acid, and add 3 drops of potassium ferrocyanide solution.

(b) *Result*—White precipitate is obtained. The precipitation is due to the proteoses, which dissolves on boiling and reappears on cooling.

(C) Colour Reactions of Proteins

Proteins show colour reactions which are due to the presence of constituent radicals in the complex protein molecule. Since different proteins contain different groups, all proteins do not give positive reaction with all colour experiments. Sometimes, non-proteins or prosthetic groups also respond to certain colour reactions and hence several tests must be done before drawing any conclusion. For colour reaction experiments prepare 5 per cent egg white solution.

Experiment No. 8. Biuret Reaction

(a) *Procedure*—Take 3 cc of 5 per cent protein soultion in a test tube, add 1 cc of 40 per cent NaOH solution to make it strongly alkaline, and then add 2 drops of 1 per cent copper sulphate solution.

(b) *Result*—Violet or pink colour appears. This reaction is due to the peptide linkage and so it is positive with all proteins.

Experiment No. 9. Ring Biuret Test

(a) *Procedure*—Take 3 cc of 5 per cent or even more dilute egg white solution in a test tube, add 1 cc of 40 per cent NaOH, then add by means of a pipette 1 cc of 1 per cent copper sulphate over the surface of the liquid very gently so that the 2 fluids do not mix. Rotate gently.

(b) *Result*—A pink or violet ring is formed at the junction of the two fluids. Proteoses and peptones give rose colour. Gelatin gives bluish pink or violet colour.

Experiment No. 10. Xanthoproteic Reaction for Tyrosine, Phenylalanine and Tryptophane.

(a) *Procedure*—Take 3 cc of 5 per cent egg white solution in a test tube, add 1 cc of conc. HNO_3 and boil. First white precipitate is formed which changes to yellow. The liquid also becomes yellow. Cool the test tube and add excess of 40 per cent NaOH or ammonia to make alkaline.

(b) *Result*—The yellow colour changes to orange. The proteoses and peptones do not form precipitate with HNO_3 but their solution turns yellow to orange in the presence of alkali. The precipitate is due to the formation of metaproteins insoluble in HNO_3 (nitric acid). The yellow colour is due to nitro-compounds from the protein molecule containing benzene ring. When made alkaline, the nitro-compounds ionize freely and produce deep yellow or orange colour.

Experiment No. 11. Millon's Test for Tyrosine

(a) *Procedure*—In a test tube take 3 cc of 5 per cent egg solution, add 2 cc of mercuric sulphate reagent by pipette and boil cautiously for a minute. A yellowish precipitate generally is formed. Cool the tube and add 2 drops of 1 per cent $NaNO_2$ (Sodium nitrite). Heat again.

(b) *Result*—The solution and the precipitate become red showing the presence of tyrosine.

Experiment No. 12. Aldehyde Test for Tryptophane

(a) *Procedure*—In a test tube add 3 cc of protein solution (5 per cent egg white), then add one drop of 0·2 per cent of 40 per cent formalin, then add 0·5 cc of mercuric sulphate reagent. Shake well and then add 2·0 cc of conc. H_2SO_4 shake.

(b) *Result*—Violet or purple colour develops. Sometimes, a little heat is required for the colour to appear.

Experiment No. 13. Glyoxalic Acid Test for Tryptophane

(a) *Procedure*—In a test tube take 3 cc of 5 per cent egg white solution for protein and add 3 cc of glyoxalic reagent. Now add this solution very carefully to another test tube containing 5 cc of conc. H_2SO_4 in such a manner that the two fluids do not mix. Rotate the tube gently.

(b) *Result*—Purplish violet colour develops at the junction of the two fluids. The purple or violet colour is due to the presence of tryptophane, which forms condensation product with the aldehyde.

Experiment No. 14. Arginine Test for Arginine

(a) *Procedure*—In a test tube take 3 cc of 5 per cent egg white protein solution, then add 2 drops of 1 per cent α-naphthol solution, then add 1 cc of 40 per cent NaOH solution, and then add 2 drops of sodium hypobromide (NaOBr).

(b) *Result*—Bright red colour is obtained. This reaction is specifically meant for arginine which is present in all proteins.

Experiment No. 15. Sulphur Test for Cystine and Cysteine

(a) *Procedure*—In a test tube take 3 cc of protein solution (5 per cent egg white), then add 5 drops of lead acetate which causes precipitation. Now add 40 per cent NaOH drop by drop till the precipitate dissolves. Boil.

(b) *Result*—Black or brown precipitate is formed, which shows the presence of cystine or cysteine group.

Experiment No. 16. Molisch's Test for Carbohydrate Group attached to Protein Molecule

(a) *Procedure*—In a test tube take 3 cc of 5 per cent egg white protein solution, then add 2 drops of 5 per cent alcoholic thymol; now incline the tube and gently add 3 cc of conc. H_2SO_4 (the acid should go by the side of the tube wall) in such a way that the fluids do not mix. Rotate the tube gently.

(b) *Result*—Purple-violet ring, at the junction of the fluids, is formed which shows the presence of carbohydrate group attached to the protein molecule.

Experiment No. 17. Ninhydrin Test

(a) *Procedure*—Take 1 cc of 5 per cent egg white protein solution and add 4 drops of 0.1 per cent ninhydrin solution and boil for 1 minute. Cool the tube.

(b) *Result*—Blue colour develops. The test gives positive results by all amino acids containing free amino and carboxylic groups. This test is positive for all proteins and their derivatives except proline and hydroxy proline.

III. FATS AND OILS

Fats and oils are found abundantly in plants and animals forming distinct foodstuff. Fats have double caloric value than the carbohydrates. Fats have greasy feel with low melting point. They are soluble in organic solvents like ether, chloroform and alcohol and insoluble in water. Fats are hydrolysed by boiling acids and alkalies. Simple fat is glycerol which forms esters with 3 molecules of the same different acids and the most common acids are—

(1) $CH_3(CH_2)_{14}.COOH$—palmitic acid.
(2) $CH_3(CH_2)_{16}.COOH$—stearic acid.
(3) $CH_3(CH_2)_7.CH=CH\ (CH_2)_7.COOH$—Oleic acid.

For experiments with fats, olive oil is quite suitable.

Experiment No. 1. Solubility Test

(a) *Procedure*—In separate ttest ubes marked A, B, C and D, take 0·5 cc of water in test tube A, 5 cc of ether in test tube B, 5 cc of chloroform in test tube C and 5 cc of alcohol in test tube D and add 3 drops of oil, preferably olive oil, in each test tube drop by drop.

(b) *Result*—Test tube A=oil is not miscible and floats.
Test tube B=oil is miscible.
Test tube C=oil is miscible.
Test tube D=oil sinks to bottom; on heating oil dissolves.

Experiment No. 2

(a) *Procedure*—In a dry test tube take 0·5 cc of olive oil, then add a knife point of sodium or potassium hydrogen sulphate and mix thoroughly by a glass rod and heat.

(b) *Result*—Observe irritating odour of Acrolin. The glycerol present gives Acrolin on dehydration.

Experiment No. 3. Emulsification of Fats

(a) *Procedure*—In a test tube take 3 cc of neutral olive oil, then add 2 drops of oleic acid, mix by shaking to form rancid oil. Now add 2 drops of this rancid oil to another test tube already containing 3 cc of dilute caustic soda.

(b) *Result*—The acid dissolves in alkali forming a soap, which entangles oil by diffusion to form **emulsion**.

Experiment No. 4. Salting out

(a) *Procedure*—Take 10 drops of olive oil in a test tube, add 2 cc of alcoholic caustic soda, boil carefully. Soap solution is obtained and divide this solution equally in 3 separate test tubes marked A, B and C. To test tube A add 3 cc of conc. HCl or H_2SO_4, to B add sodium chloride powder and to C add 2 per cent calcium solution. Observe.

(b) *Result*—Test tube A=small oil globules separate and float on the surface.
Test tube B=white precipitate separates and floats on the surface.
Test tube C=white precipitate of calcium soap is formed.

ENZYMES

Enzymes act as catalyst for the chemical reactions. They are colloidal organic protenaceous substances, whose activities are entirely independent of any of the life processes. Enzymes act only on a particular substrate. In animals, enzymes are most active between 35°C–44°C. Several enzymes occur in inactive form and are activated by specific substances. For example, inactive pepsinogen is transformed into active pepsin by HCl from the gastric glands.

Experiment with Ptyalin

Ptyalin is a salivary enzyme called as amylase and it acts on starch dextrin and glycogen converting them into maltose. Salivary digestion of starch can be demonstrated.

(a) *Procedure*—In order to obtain your own saliva, rinse your mouth with mouthful of water to remove acidity. Again keep 10–15 cc of water into mouth and rotate it by tongue for 2 minutes, then collect the water in a beaker. For collecting saliva warm water between 38°C–40°C is preferably employed. Tap water may not give satisfactory result. Now take a porcelain tile test tablet having depressions. Add 2 drops of 0·02N iodine solution in each depression. Now take another test tube and mix 5 cc of 1 per cent starch paste plus 5 cc of saliva solution obtained from your mouth thoroughly. By means of a pipette take some mixture and add a drop to one of the depressions in the test tablet containing iodine solution.

(b) *Result*—Blue colour is obtained due to the presence of the starch.

EXERCISE No. 1

Object—To identify the given substance.

No.	Experiments	Observations	Inference
1.	Substance+Water→Shake.	Subs. completely dissolves.	Carbohydrate.
2.	3 cc H_2O+Methylene blue+0·5 cc of NaOH. Boil→Add 1 cc of glucose soln.	The colour disappears.	Sample is carbohydrate.
3.	3 cc Pot. ferricyanide soln.+1 cc NaOH→Boil.	Yellow colour of ferricyanide starts fading and ultimately disappears.	Sample is carbohydrate.

No.	Experiments	Observations	Inference
4.	2 cc $CuSO_4$ + Soln. + 2 cc NaOH→Boil.	Blue solution appears and becomes brick-red on boiling.	Sample is carbohydrate.
5.	5 cc Fehling's Soln. + 1 cc Soln.→Boil.	Brick red ppt. of Cu_2O appears.	Sample is carbohydrate.
6.	5 cc Benedict's qualitative soln.+Soln.→Boil and cool under tap.	Red ppt. of Cu_2O appears.	Sample is carbohydrate.
7.	3 cc Soln.+1 cc Sat. Picric acid soln.+1 cc NaOH.	Red colour develops.	Sample is carbohydrate.
8.	5 cc Soln.+5 cc of Nylander's reagent, heat→Boil. *Perform other tests.*	Solution becomes dark black.	Sample is carbohydrate.

Result—The given carbohydrate was identified.

EXERCISE No. 2

Object—To identify the given samples A, B and C of Carbohydrate.

No.	Experiments	Observations (Write Positive or Negative)	Inference
	Sample (A)—		
1.	Sample+H_2O → Shake.	Sample easily dissolves.	Sample may be sugar.
2.	Methylene blue test	Positive	
3.	Pot. ferricyanide test.	,,	
4.	Tommer's test.	,,	
5.	Benedict's test.	,,	
6.	Fehling's test.	,,	Sample is carbohydrate.
7.	Picric acid test.	,,	
8.	Nylander's test.	,,	
9.	Rapid Furfural test.	,,	
10.	Soln.+3 cc. lead acetate→boil +NH_4OH→boil.	A pink colour is obtained.	Sample is glucose.

No.	**Sample (B)**—		
1.	Methylene blue test.	Positive	
2.	Pot. ferricyanide test.	,,	
3.	Tommer's test.	,,	
4.	Benedict's test	,,	
5.	Fehling's test.	,,	
6.	Picric acid test.	,,	
7.	Nylander's test.	,,	
8.	Seliwanoff's test.	Negative	
9.	Soln.+3 cc lead acetate → boil+ NH_4OH→boil.	A red colour is obtained.	Sample is maltose

No.	**Sample (C)**—		
1.	Methylene blue test.	Positive	
2.	Pot. ferricyanide test.	,,	
3.	Tommer's test.	,,	
4.	Benedict's test.	,,	
5.	Fehling's test.	,,	
6.	Nylander's test.	,,	
7.	Barfoed's test.	,,	
8.	Furfural test.	Negative	
9.	Soln.+H_2SO_4+ HNO_3→heat+70° warm water→heat.	A sandy ppt. appears.	Sample is Lactose.

Result—Sample A—Glucose. Sample B—Maltose. Sample C—Lactose.

EXERCISE No. 3

Object—To identify the given sample.

No.	Experiments	Observations	Inference
1.	Biuret test.	Positive	Sample is protein.
2.	Xanthoproteic test.	,,	,,
3.	Millon's test.	,,	,,
4.	Aldehyde test.	,,	,,
5.	Arginine test.	,,	,,
6.	Molisch's test.	,,	,,
	Perform other tests.		

Result—The given sample is protein.

EXERCISE No. 4

Object—Identification of the given substance.

No.	Experiments	Observations	Inference
1.	Sample + $NaHSO_4 \rightarrow$ heat.	Irritating smell.	Sample is oil.
2.	Sample + Oleic acid $\rightarrow$ shake + NaOH.	Soap is formed.	Sample is oil.
3.	Sample + Alcoholic KOH $\rightarrow$ boil and divide it into 3 parts in test tubes.		
	First T.T. + conc. HCl.	Oil separates and floats on surface.	Sample is oil.
	Second T.T. + NaCl.	White ppt.	Sample is oil.
	Third T.T. + $CaCl_2$.	White ppt.	Sample is oil.
4.	Sample + $KMnO_4$ + HCl + Alcoholic KOH $\rightarrow$ heat.	The colour produced decolourises.	Sample is unsaturated fatty acid.

Result—The given sample is oil.

Chapter **9**

Meiosis and Mitosis

(A) STUDY OF DIFFERENT MEIOTIC STAGES USING GRASSHOPPER OR COCKROACH TESTIS

Note :—*Meiotic stages are found only in sex-cells and for this purpose testis is the most suitable material to study. During Meiotic cell divisions, reduction of* **diploid** *chromosomes to* **haploid** *number occurs. The entire meiotic division comprises of two main divisions* : (1) **First meiotic division** *in which pairing, crossing and reduction in the number of chromosomes occurs*; (2) **Second meiotic** *division in which 4 daughter cells with haploid number of chromosomes are formed.*

(1) Requirements

Animal—Grasshopper or cockroach,

Glassware—Petri-dishes, 6 cm slides, cover-slips, micropipettes, droppers.

Fixative—Carnoy's fluid (Aceto-alcohol).

Stain—Acetocarmine or Aceto-ovecin.

Other articles—Filter paper, spirit lamp, levels.

(2) Procedure

(1) Grasshoppers may be collected from the green fields during the rainy season in the morning hours. If required in large numbers, they may be fixed in Carnoy's fluid and preserved in 90 per cent alcohol.

(2) Pin down the living grasshopper in insect dissecting dish.

(3) Dissect the animal in 0.78 per cent NaCl solution (normal saline).

(4) Take out the testes lobes and fix them in Carnoy's fluid for 2–12 hours.

(5) Stain the Carnoy's fluid fixed testes lobes in **acetocarmine** or **propiono-carmine** for 5–40 minutes, depending upon the nature and the size of the material.

(6) If the material is over stained, dip in 45 per cent glacial acetic acid.

(7) For squash preparation, take a clean slide and keep the material over the slide in 2–3 drops of glacial acetic acid, cover it with a thin cover-slip and heat it very gently.

(8) Place a filter paper over the slide and apply a uniform pressure with the thumb keeping the slide on the table.

(9) The slide can be sealed by nail polish or half wax and half canada balsam.

(10) Study the different meiotic stages with special emphasis on the following stages :

Meiosis I

(a) **Prophase I**—It consists of the following substages—

(i) ***Leptotene***—Chromosomes thin, long, slender and ramified.

(ii) ***Zygotene***—Chromosomes, thick and short. Homologous chromosomes pair with each other. Process of pairing is called as synapsis which generally begins at centromeres.

(iii) ***Pachytene***—Nucleolus present. The paired chromosomes look still shortened, thick and in the form of network.

(iv) ***Diplotene***—The chromatids look separated. The bivalents look double structures due to terminalization effect and **chiasma** formation. The thick and shortened bivalents are countable. Nucleolus present.

(v) ***Diakinesis***—Nucleoli and nuclear membrane begin to disappear. Tetrads contract and each lies separately.

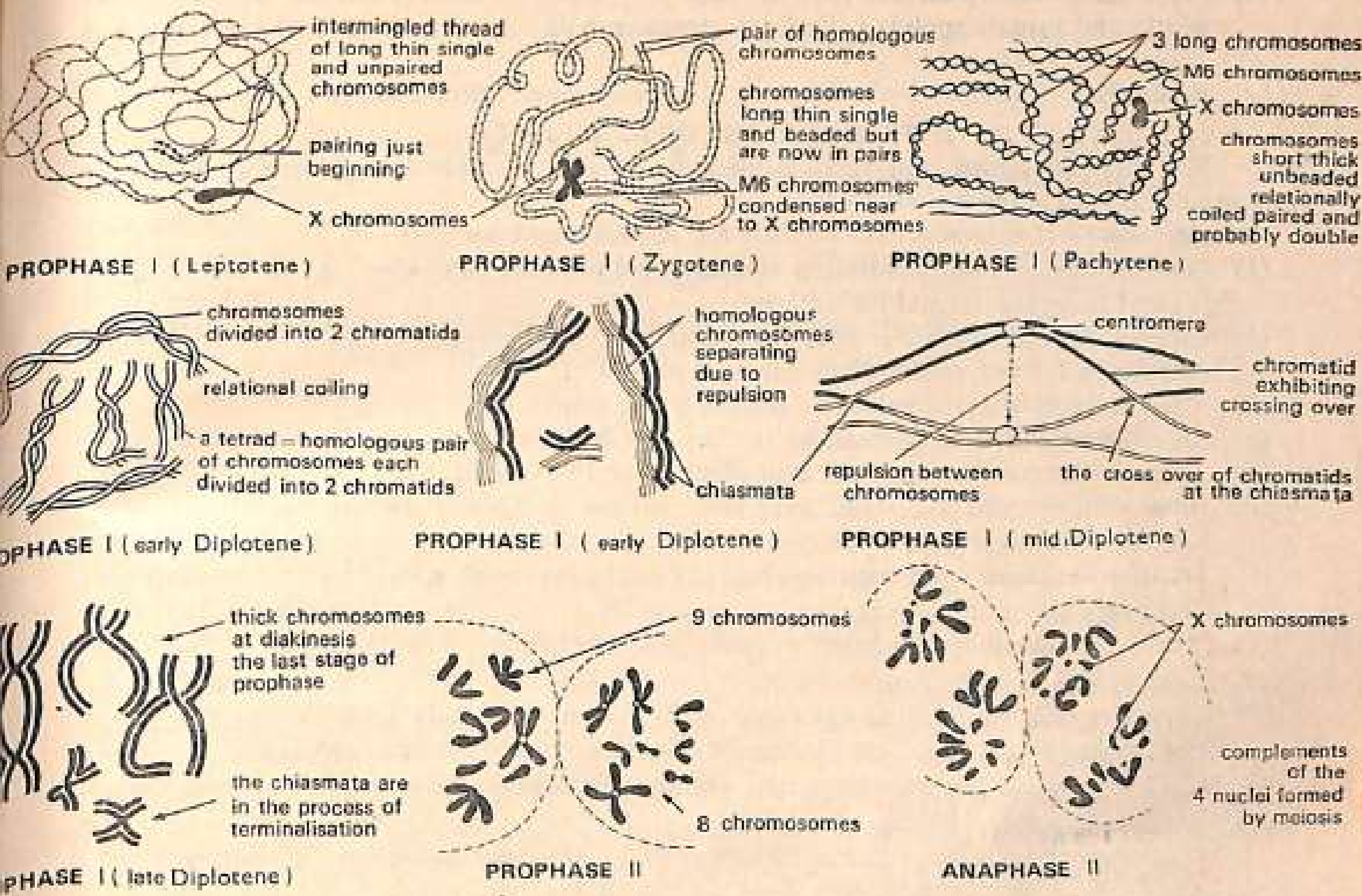


Fig. 9-1. **Meiosis.** Different stages.

(b) **Metaphase I**—The chromosomes move to equatorial plane with their centromeres facing the poles.

(c) **Telophase I**—Cytokinesis may or may not take place.

Meiosis II

(a) **Prophase II**—Chromatids appear as dyads. Nuclear membrane and nuclei disappear.

(b) **Metaphase II**—Spindle is formed. Chromatids move towards equatorial plane with centromeres facing the poles.

(c) **Anaphase II**—Centromeres of the dyads separate and move towards poles. Each chromosome splits in two haploid number.

(d) **Telophase II**—Chromatids are found at two opposite poles. Nuclear membrane and nucleolus reappear.

(B) STUDY OF SALIVARY GLAND CHROMOSOMES

Procedure

(1) Take a full-grown third instar larva of insect and place it over a slide in a drop of normal saline (0.78 per cent NaCl) or Ringer's solution.

(2) Cut the head of the larva with the scalpel and press the body with the needle. The salivary glands float.

(3) Stain the glands in 2 per cent aceto-ovecin for about 5 minutes on the slide.

(4) Place the cover-slip on the tissues, suck the excess of stain from the dropper, heat gently and squash applying uniform pressure with the thumb over the filter paper covered cover-slip.

(5) Study the banded polytenic structure of salivary gland chromosomes.

(C) STUDY OF DIFFERENT MITOTIC STAGES

For study of mitosis, intestinal epithelium or bone marrow are preferably taken or any rapidly dividing and growing tissue.

Procedure—(Feulgen squash method for mammalian bone marrow)—

(1) Give an intraperitoneal injection of 5 cc of 0.4 per cent colchicine in an experimental rat and leave the animal for an hour.

(2) Chloroform the animal, remove the femur, cut the epiphysis and collect the bone marrow in 1.2 per cent sodium citrate kept at 37°C.

(3) Mix the marrow with the needle so that a fine suspension is made.

(4) Fix the suspension of the marrow in Carnoy's fluid (aceto-alcohol) for 10 minutes.

(5) Transfer the marrow in 50 per cent alcohol for 15 minutes.

(6) Rinse with distilled water and keep the marrow in normal HCl to hydrolyse at 60°C for 4 to 7 minutes.

(7) Transfer the tissue from bath immediately in the ice cold water for 1–2 minutes to stop hydrolysis.

(8) Stain it in leuco-basic Fuchsin for about one hour and keep the tissues in 45 per cent acetic acid.

(9) Prepare squash preparation as described for meiosis and study the following stages—

(a) **Prophase**—Chromosomes become distinct and coiled around each other.

(b) **Metaphase**—The chromosomes occupy equatorial plate and their centromeres facing opposite poles.

(c) **Anaphase**—The two chromatids separate at the centromeres which move apart. Chromosomes become V or L–shaped in appearance.

(d) **Telophase**—Chromosomes move towards poles. New nuclear membrane and nucleoli appear. It is followed by cytokinesis and two daughter cells are formed with equal number of chromosomes.

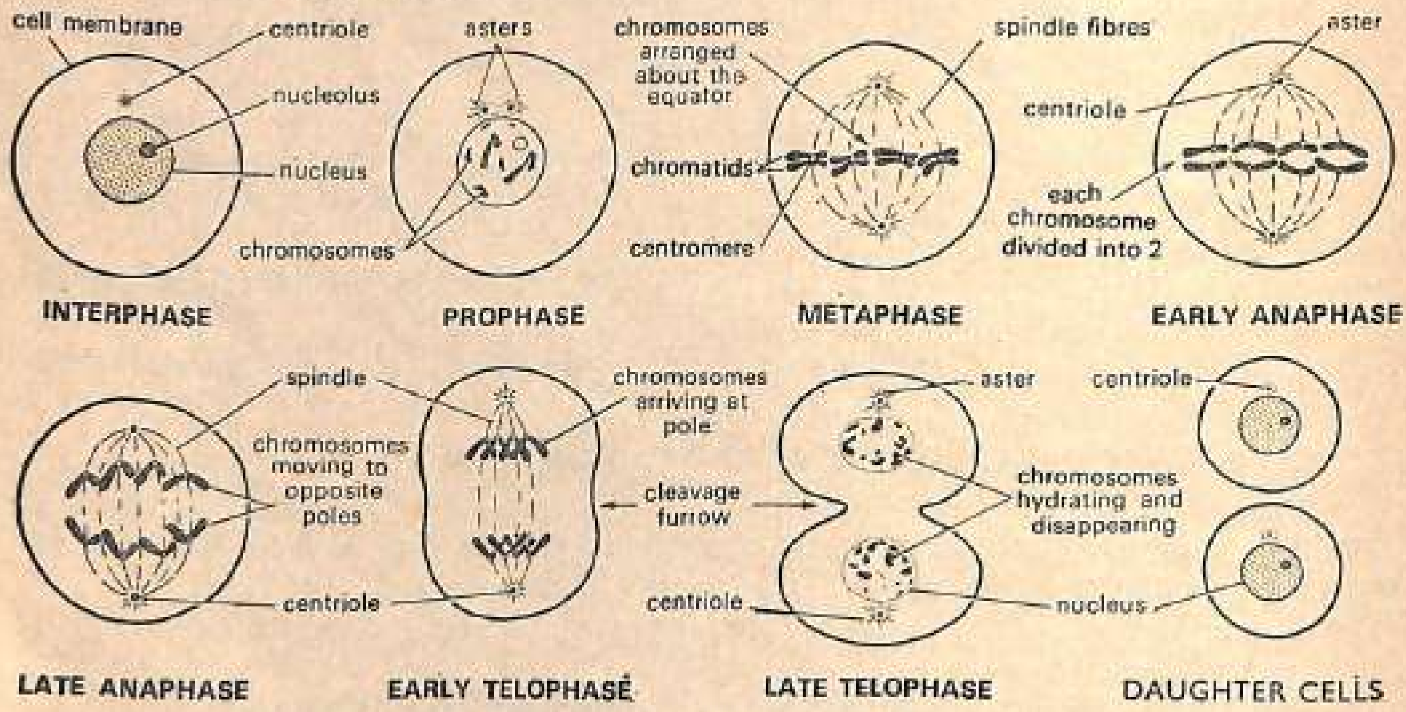


Fig. 9-2. **Mitosis.** Different stages.

Chapter **10**

Heart Beat and Muscle Contraction

EXPERIMENT 1

Object—Study of Apparatus Commonly Used for Heart Beat and Muscle Contraction Experiments

Recording drum is used for above experiments. Complete apparatus used for such studies is divided into two categories—(A) **Non-electrical parts**, and (B) **Electrical parts.**

(A) Non-Electrical Parts

These consist of the following—

(1) **Dissecting board**—It is a rectangular wooden board of $6'' \times 8''$ size containing elastic bands on 4 corners to fix 4 extremities of the frog (hand and feet).

(2) **Rectangular tray**—It is made up of aluminium or stainless steel measuring $8'' \times 10''$. It is deep enough to accommodate the dissecting board.

(3) **Adjustable stand**—It is composed of a heavy metal base and long vertical middle rod having a screw near its base, so that it may be rotated.

(4) **Myograph board**—It is covered with paraffin wax on top. On one side it has a top or head for fixing it to myograph lever, while on the other side a fork is attached. The top surface is provided with raised margins to keep Ringer's solution for keeping the nerve-muscle preparation moist.

(5) **Myograph lever**—It magnifies the contractions. It is a crank type of myograph lever in which the fulcrum of the lever is near one end of the myograph board. The lever has a vertical short stem and a long horizontal arm. The muscle can be loaded by hook and the weight is hung over the long arm. It can be adjusted in such a way that the muscle and the thread are not freely stretched by the load during rest.

(6) **Pithing needle**—It is used to pith and kill the frog.

(7) **A pair of hand gloves.**

(8) **Recording drum**—It comprises of both mechanical and electrical parts. It is composed of a heavy metal base with two screws in front for levelling. The drum is electrically operated having an electrical switch at right side to control the main power of 220 volts. Below this is a mechanical screw. This screw keeps the drum off, if placed horizontally, and on when in vertical position. For speed control there are two bars on left side. These bars are fitted in marked end and the drum will not move if it is at neutral point. At the base of the drum, there is a vertical metallic rod, which rotates and possesses a hollow metallic cylinder of 6″ long. Over the rod is a guiding pin through which the slot of drum must pass. The outer surface of the drum is tightly covered by a glazed and smoked paper for recording the contraction or the heart beat.

(B) Electrical Parts

These consist of the following—

(1) **Recording drum**—The electrical part of the drum consists of two terminals, one black and other red, connected to the source of the current. The lower end of the rod contains two metallic pins. Inside the terminals is a metallic spring which gives contact-make and contact-break, during each rotation.

(2) **Induction coil**—It is used to convert low voltage current to high voltage. It is composed of primary and secondary coils. When the current passes through the primary coil, there is a change of flux and an induced current is produced in secondary coil. This change is brought about by make and break arrangement. The primary coil is of thin copper wire wrapped on a soft iron core and a secondary coil of thin copper with large number of turns. The secondry coil may be kept close or away from the primary circuit.

(3) **Keys**—The keys are used for interrupting the course of the current. For adjusting primary circuit, short circuiting is used and for secondary circuit, secondary key or Du Boys Reymond key is used.

The drum must always be rotated clockwise and the mechanical screw must be kept off.

EXPERIMENT 2

Object—To Prepare Gastrocnemius Muscle Nerve

(1) **Procedure**—While making nerve muscle preparation, the following rules must be observed :

(a) Never use a knife when experimenting on a frog, but cut with scissors only.

(b) Do not touch the nerves with instruments.

(c) Always keep the tissues, especially the nerve moist with 0.6 per cent NaCl solution.

(d) Always pith the frog for above preparation.

(2) For pithing, take a living frog and catch it firmly in the left hand. Make a bold incision into the skin transversely along outside cutting the atlanto-occipital ligament and pass the pithing needle into the skull above the exposed spinal cord to destroy the central nervous system by moving the needle to and fro, forwards and backwards. Take out the needle, pass it downwards through vertebral canal perfoming side to side movement of the pithing needle so as to destroy the spinal cord. The complete destruction of the spinal cord is ensured by the absence of cutaneous reflex of the hind limbs.

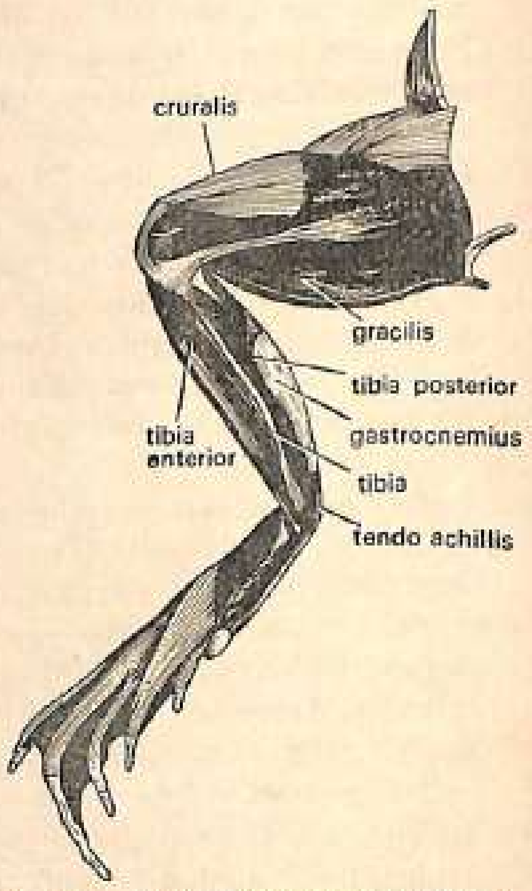


Fig. 10-1. Frog. Gastrocnemium mucle.

(3) Cut the pithed frog across about 1 cm anterior to the sacro-iliac joints, remove any viscera remaining in the body cavity. Cut the skin between the legs, catch the skin at the transverse cut with the finger and thumb of one hand and the end of the spiral column with the other and pull the skin downwards towards the toes. It will be peeled off easily and cleanly. Leave the second leg covered with skin.

(4) Lay the legs on their ventral surface, grasp the urostyle with forceps and remove it by cutting away the muscle on both sides, and finally cut it from the end of the spinal column. Turn the preparation to the dorsal side and observe the sciatic nerve lying

against the back of the abdominal cavity. Snip through the sacro-iliac joint on the side of the skinned leg, dissect the end of the spinal column longitudinally, by means of one strong steady cut with scissors, carefully avoiding injury to nerves. By holding the piece of vertebrae so isolated, the dissection of the nerve can be carried out without pinching it with forceps. Lay the preparation on the ventral surface and pin it firmly to the dissecting board.

(5) Now holding the piece of the bone with forceps, dissect the nerve down towards the thigh, separate the muscular masses on the dorsal side of the thigh, carefully keeping in mind for the sciatic nerve and artery lying side by side. Continue the dissection upto the knee, do not let the nerve lie on the skin of the frog, moisten with normal saline. Tie a ligature round the **Achilles tendon,** cut this on distal side, snip through connective tissue attaching the **gastrocnemius** muscle to the leg. Cut through the leg bone just below the knee, and the whole thigh just above the knee, carefully leaving gastrocnemius muscle and the sciatic nerve intact. Don't dissect the nerve at the knee.

(6) The nerve muscle preparation is now complete which consists of vertebrae with origins of sciatic nerve, knee joint, gastroncnemius muscle, tendon and thread. Fasten it on to the myograph board with a pin through the knee joint, attach the thread to the short arm of the lever, so that preparation is ready for experimentation.

EXPERIMENT 3

Object—To Demonstrate or Draw a Simple Muscle Curve (Simple Twitch)

Requirements—Dissecting board, adjustable stand, crank myograph, pointer, recording drum or kymograph, primary key, induction coil, short circuiting key, electrodes, connecting wires, pithing needle, scalpel, scissors and hand gloves.

Connections—It consists of primary circuit with drum in circuit. In the secondary circuit, the two terminals of secondary coil are connected to the two side terminals of the short circuiting key. The current from the other two terminals of the short circuiting key is led to the electrodes which are used to stimulate the muscle through its nerve. The speed of the drum is kept fast.

Procedure—(1) After making all the necessary connections, adjust the base of the recording drum in the horizontal position by levelling the screws. Wrap the smoked paper around the recording drum and make a base line on the recording drum.

(2) Place the **gastrocnemius sciatic** preparation on the myograph, connect the tip of the muscle with the vertical limb of the myograph liver and insert a pin below the knee joint. The other end of the sciatic nerve is laid on the electrodes. Adjust the pointer on the drum to draw the curve.

(3) Apply the current on the nerve.

Observation—When the electrical stimulus is applied to the sciatic nerve, the gastrocnemius muscle contracts and a curve is drawn on the smoked paper. This curve shows movement of stimulus, latent period, phase of contraction and phase of relaxation.

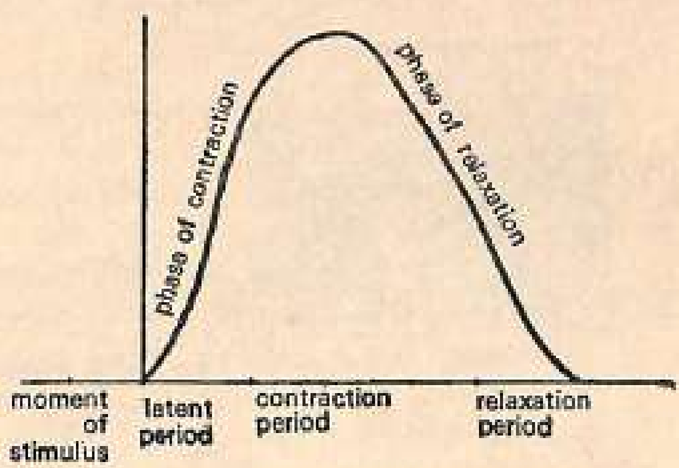


Fig. 10-2. Simple muscle twitch curve.

Precautions—(1) Switches should be used very carefully.

(2) Connections should be tight.

(3) Plane of recording drum must be in the horizontal position.

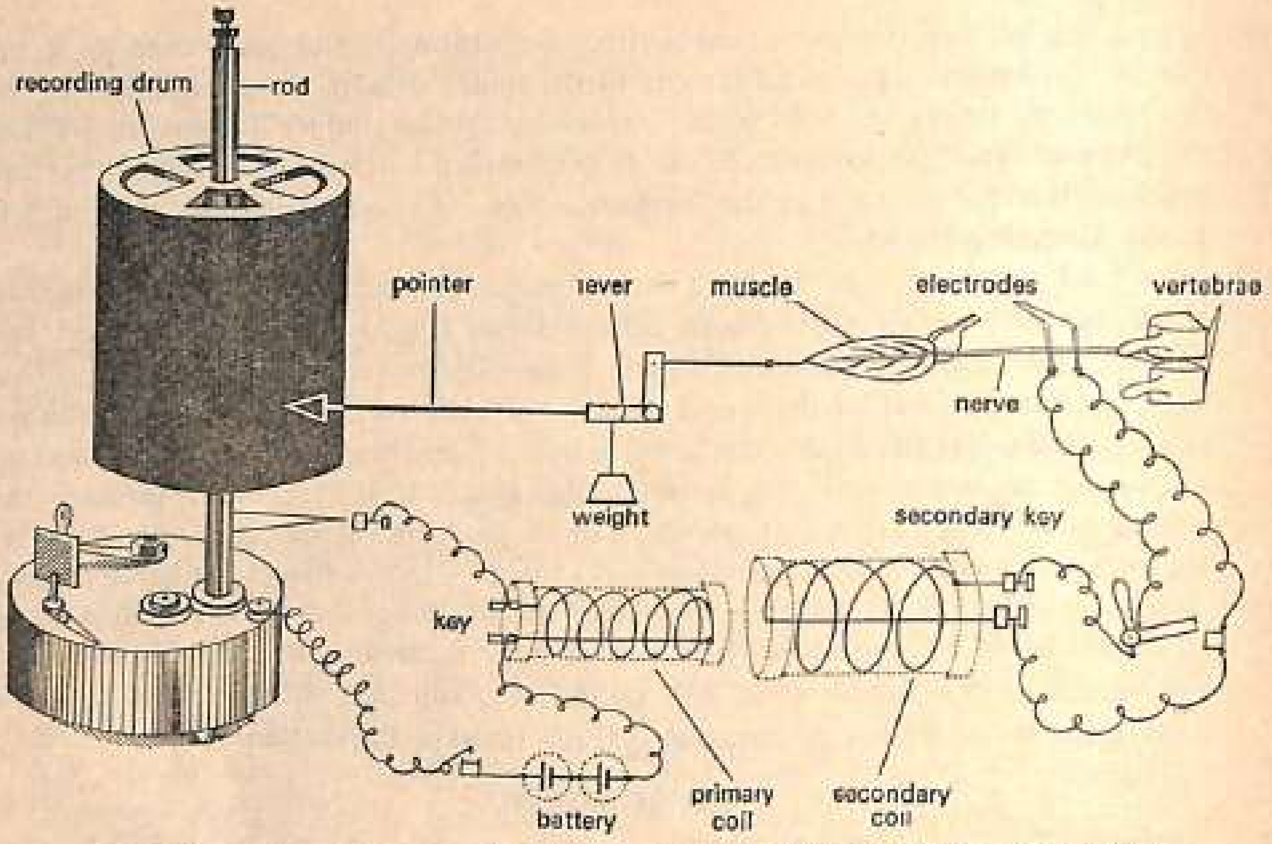


Fig. 10-3. Connections, recording drum and nerve muscle for simple muscle twitch.

EXPERIMENT 4

Object—To Demonstrate the Phenomenon of Complete Tetanus.

Apparatus—As given in the case of muscle twitch. The connections are adjusted in such a way that the rate of movement of the hammer of induction coil becomes very high and the speed of the drum is kept very slow.

Procedure—Fix a gastrocnemius muscle preparation on the myograph board. Draw a base line on the drum. Rotate the drum very slowly. Give one stimulus to cause muscle contraction, then give multiple stimuli.

Observation—A complete **tetanus** curve is observed. It was observed that, due to very high rate of movement of the hammer of induction coil the rate of interruptions of the current becomes very fast and successive contractions fused together as a continuous curve.

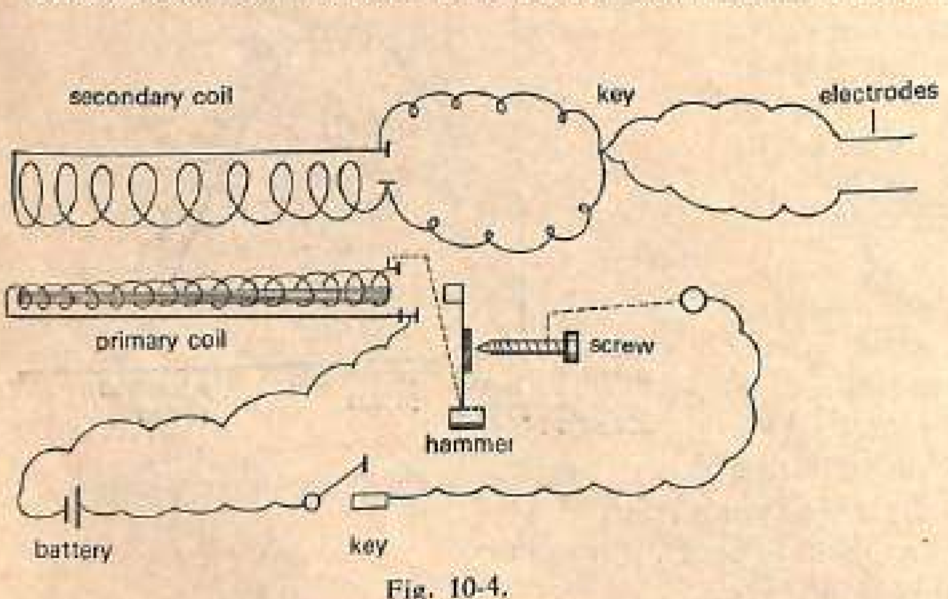


Fig. 10-4.
Connections for tetanus.

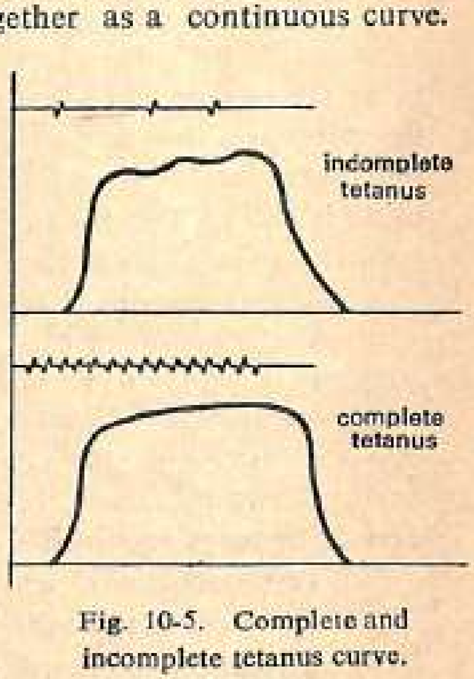


Fig. 10-5. Complete and incomplete tetanus curve.

The rapid and multiple stimulations to muscle fibers leave no time to relax them. The response is smooth, sustained and maximal. Such a response is termed as **tetanus.** For demonstrating **incomplete tetanus** less rapid stimulations are given. In this case, contraction is not smooth and individual waves may be discerned. If a muscle is stimulated respectively for a long enough period of time, the force of contraction progressively decreases and finally a point is reached at which no contraction occurs. In this case a muscle is said to be fatigued.

EXPERIMENT 5

Object—To Record the Heart Beats of the Frog in Situ.

Apparatus—Recording drum, myograph board, dissecting board, pithing needle and large frog.

Dissection of frog's heart—(1) Lay the pithed frog on its back on the frog board and fix it with 5 pins—four through the limbs and one through the jaw.

(2) Make a median incision through the skin over the sternum, lift the cartilaginous xiphisternum and separate it from underneath by cutting through the small strands of tissue. Make an incision on each side of the cartilage, insert under the pectoral girdle the pointed blade of a pair of strong scissors, keeping the blade in close contact with the bone.

(3) Divide the girdle first on one side and then on the other, raise and cut away the anterior wall of the thorax. Pull both forelimbs laterally and fix them in such a position as to keep the chest wide open.

Inspection of the frog's heart—Carefully make an incision in the pericardium and find the **ventricle**, two **auricles**, auriculo-ventricular groove and bulbous arteriosus. Lift the ventricle upwards and locate the sinus venosus, superior and inferior venae cavae.

Sequence of the heart beat—The contractions of the frog's heart are progressive. The sinus leads off first and is followed by the auricles, ventricle and the bulbous last. The rhythm of the heart beat is dependent on the frequency of the sinus. Observe how the ventricle, during contraction, changes its colour becoming pale when free from blood in **systole.** Also observe the short pause between the contraction of the sinus and the auricles and between that of the auricles and ventricle.

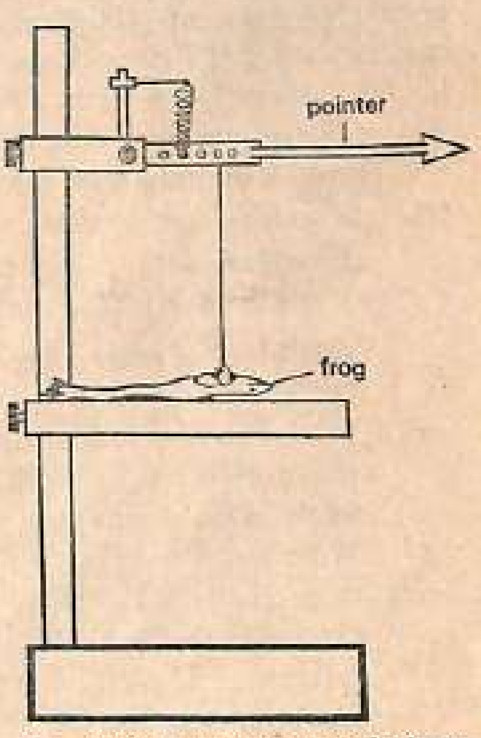


Fig. 10 6. Heart beat record of frog.

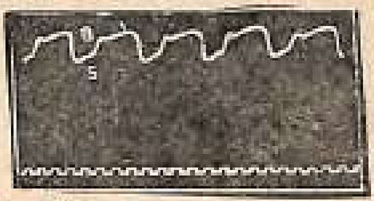


Fig. 10-7. Normal heart beat recording of frog; s, contraction of sinus; a, contraction of auricle; v, contraction of ventricle.

Record of the heart beat—Pass a hook, made from a small pin, in the apex of the ventricle or use a special heart clip. Lift the heart very gently by the thread attached to the hook and snip through the fraenum. Insert a pin through the bulbous part and fix it to the frog board. Fasten the free end of the thread with the lever and adjust the lever over the drum. Record the movements of the beating of heart on a slowly moving drum.

Precautions—(1) During dissection never use the knife. Use scissors only. (2) Never injure the heart. (3) Select a large frog. (4) Once the frog has been pithed, perform the experiment with as much speed as you can. (5) Never pinch the nerves with forceps. (6) Prevent the tissues from drying by frequently bathing them with 0·78% NaCl solution.

Chapter **11**

Experiments with Blood

EXPERIMENT 1

Object—Enumerate the Total R.B.C. (Red Blood Cells or Erythrocytes) Count of your Own Blood

Apparatus—Haemocytometer, pricking needle, R.B.C. pipette, compound microscope and Hayem's diluting fluid (NaCl—1 per cent, Na_2SO_4—2·5 per cent and $HgCl_2$—0·25 per cent).

The **Haemocytometer** is a kind of slide containing counting chambers. The **Burker**, **Neubaur**, **Thoma** or any other Haemocytometer may be used. The Neubaur haemocytometer consists of a double-cell slide with two sunk platforms in open cell type. Each platform has a ruling so that rapid duplicate counts can be made. When a special cover glass is kept in position, a depth of 1/10 mm. is maintained over the rulings. The diluted blood is run in by capillary after the cover glass has been fixed. The counting chambers are nine large squares having sides of 1 mm each. The **central large** square ABCD is subdivided in 25 **medium** squares and each medium square in turn contains 16 **tiny** squares having sides 0·05 mm. long.

Hayem's diluting fluid may be kept as stock solution and a small amount of it may be taken in watch-glass, so that entire solution may not be mixed with the blood.

Procedure—(1) Clean and dry the mixing pipette (dilution 1 : 200).

(2) Sterilise your middle finger and the puncturing needle (preferably over a flame) with a small pad of cotton wool dipped in 90 per cent alcohol.

(3) Prick the middle finger with the puncturing needle so that blood flows freely. Don't squeeze.

(4) Wipe away cleanly the first few drops, then suck the blood with R.B.C. pipette upto the 0·5 mark slowly and carefully. If the blood has been drawn up too far, the excess may be removed by wiping the end of the pipette suitably inclined on blotting paper.

(5) Wipe the excess blood from the tip of the pipette and immediately mix it with Hayem's diluting fluid and suck in R.B.C. pipette the diluted blood upto 101 mark. Hayem's fluid prevents haemolysis, rouleaux formation, coagulation and bacterial growth. Disconnect the rubber tube, grip the ends of the pipette between forefinger and thumb and shake thoroughly for one minute.

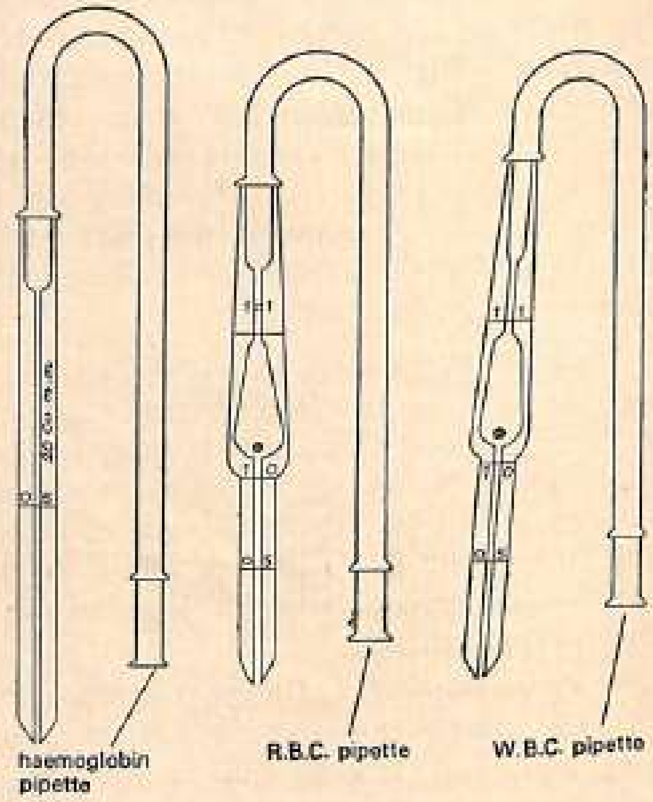


Fig. 11-1.
R.B.C., W.B.C. and haemoglobin pipettes.

(6) Re-attach the rubber tube to the pipette, reject the unused diluting fluid in the stem of the pipette. Avoid drying and quickly run the diluted blood under the cover glass on to each of the central platforms. If unable to do so, wash the slide and the cover glass and repeat it until you become expert. The acquirement of skill in performing procedures No. 3 and 6 is very essential and untill the counting is valueless. The correct size of the blood drop and speed is obligatory, in order to avoid uneven distribution of the cells. Very large drop will result in low count because the cells tend to be sucked down into the trough away from the counting grid. On the contrary, a very small drop, so that a second drop is to be added, results in high count due to the uneven distribution of cells at the junction of the two drops. Once an optimum drop has been placed, the cells should be allowed to settle for one minute and then counting should be done.

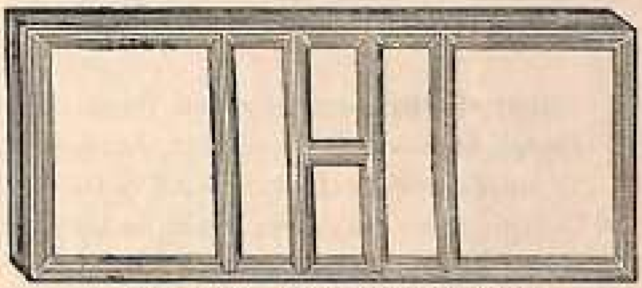


Fig. 11-2. The Burker Hawksley counting slide.

(7) Bring counting scale into the focus under the objective under a microscope. Count cells in 16 squares in five different parts of the field. The counting should be done in exact replica of the squares drawn on your copy. Any corpuscle lying on lines should be moved either upwards or to right side.

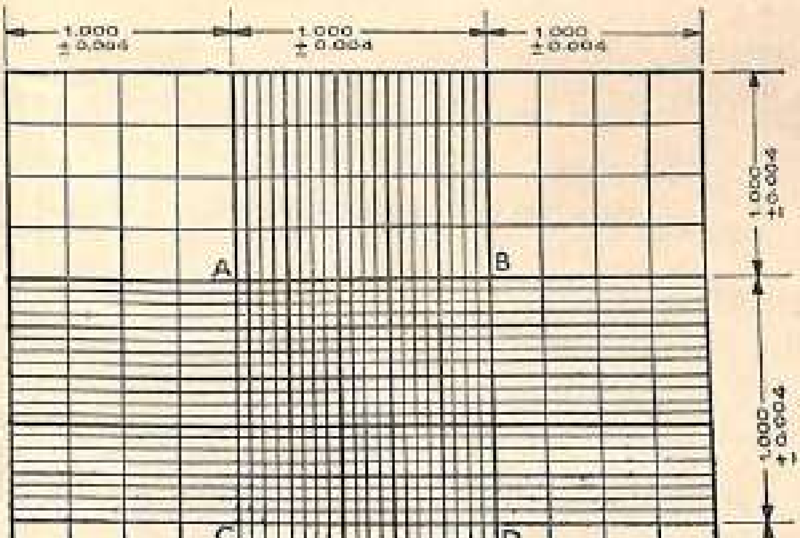


Fig. 11-3.
Ruling of the improved Neubaur slide.

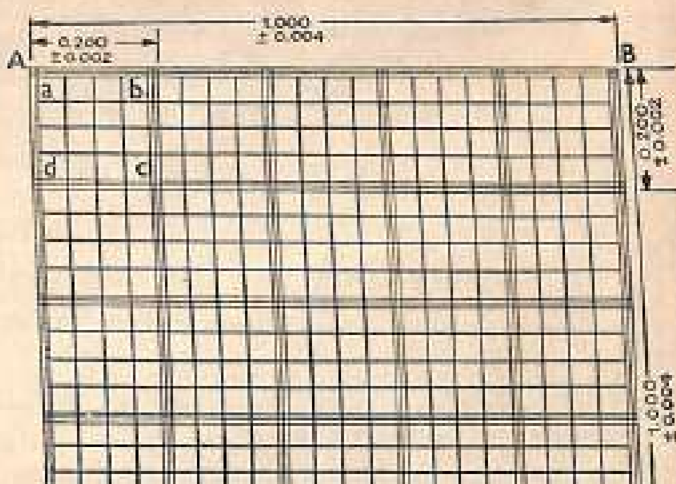


Fig. 11-4.
Magnified view of the central ABCD square.

Calculations—These may be done in the following manner—

$$\text{Number of R.B.C. per cubic mm.} = \frac{\text{Number of cells counted} \times \text{Dilution} \times 4000}{\text{Number of small squares counted}}$$

Suppose, five smaller squares or 80 smallest squares contain A+B+C+D+E R.B.Cs.
One smallest square will contain A+B+C+D+E/80 R.B.Cs.
400 smallest squares will contain A+B+C+D+E×400/80 R.B.Cs.
But, height of chamber=0·1 mm. and dilution of blood=200 times.
Therefore, one cubic mm. of blood will contain

$$\frac{A+B+C+D+E}{80} \times 400 \times 10 \times 200 \text{ R.B.Cs.}$$
$$= A+B+C+D+E \times 10000 \text{ R.B.Cs.}$$

EXPERIMENT 2

Object—Enumerate the Total W.B.C. (Leucocytes) Count of your Own Blood

Apparatus—W.B.C. pipette, haemocytometer, Hayem's fluid, microscope.

Procedure—(1) Clean and dry the W. B. C. pipette.

(2) Sterilise the tip of your middle finger and puncturing needle with a pad of small cotton wool dipped in 90 per cent alcohol.

(3) Prick the sterilised finger deeply with the needle so that blood oozes freely without squeezing.

(4) Discard the first drop and then suck the blood in W.B.C. pipette upto 0·5 mark and immediately dilute the blood with Hayem's solution 20 times upto 11 marks.

(5) Rotate the pipette slowly so as to allow the blood to mix with diluting solution.

(6) Place clean covership on already cleaned counting chamber and add immediately and rapidly a drop of mixture to the edge of the covership after discarding the clear fluid in the capillary part. Allow the corpuscles to settle down and make a count under the microscope.

(7) The white cells are recognised under low magnification by their refractile appearance and by slight colour given to them by the diluting fluid. The counting is performed in the four corners of 1 square millimeter.

Calculations—The number of leucocytes per cubic mm. is calculated as follows :

$$\text{Number of leucocytes per cubic mm.} = \frac{\text{Number of cells counted} \times \text{Dilution} \times 10}{\text{Number of 1 sq. mm. counted}}$$

EXPERIMENT 3

Object—Find out the Haemoglobin Percentage of your Own Blood.

Requirements—Haemoglobinometer and N/10 HCl.

Procedure—(1) Prick the finger as described earlier, discard the first drop and suck the blood in the pipette upto 0·2 ml. mark.

(2) Transfer the blood into the carefully cleaned haemoglobinometer tube containing small amount of N/10 HCl.

(3) Add N/10 HCl again drop by drop into the tube and constantly match the colour of the mixture with the colour of adjacent tubes of either side of the instrument. Continue this until the colour of the mixture exactly matched with the standard colour.

(4) Find out the end point. It may be found out by noting the point where the colour of the solution becomes lighter on addition of very next drop. Take more than one reading to avoid error. The amount of haemoglobin in the above experiment comes to 14·5 gm. By addition of N/10 HCl, a definite quantity of haemoglobin is converted into acid Haematin.

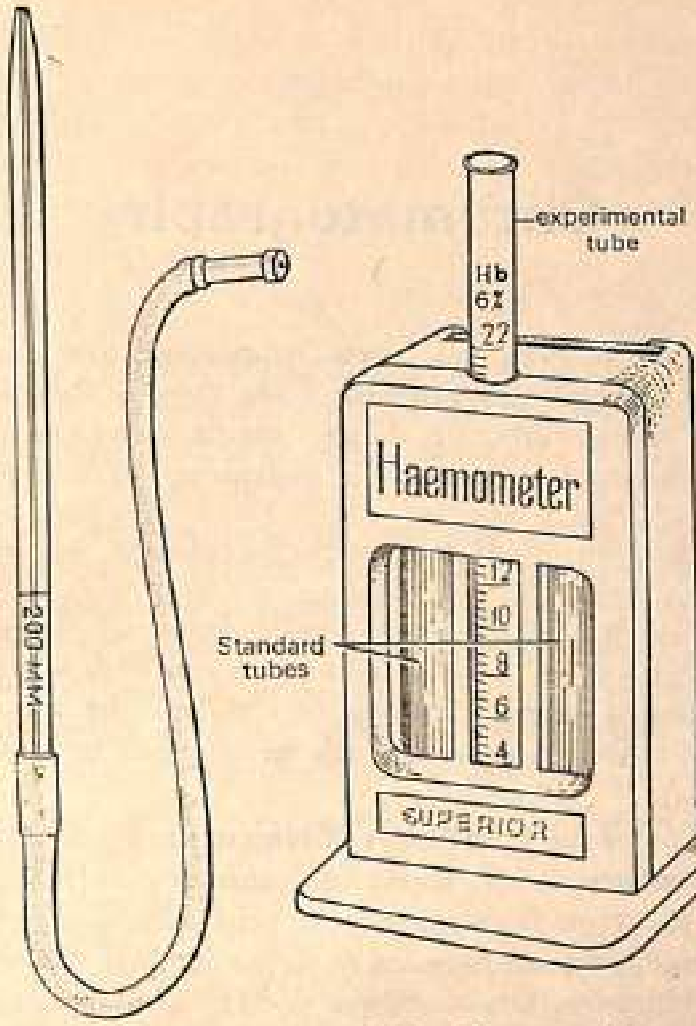


Fig. 11-5. Gower's Haldane Haemometer.

EXPERIMENT 4

Object—Preparation of Haemin Crystals.

Procedure—(Haemin crystals may be prepared from your own blood).

(1) Wash your hands with the soap, clean the middle finger with the rectified spirit and allow it to dry in the air.

(2) Prick this cleaned finger with the sterilized needle smartly and take a drop of blood on the clean slide.

(3) Allow the blood to dry completely.

(4) Put a drop of glacial acetic acid and dry the slide over the Bunsen's burner or spirit lamp.

(5) Cool the slide and examine it under microscope.

Observation—Steel grey small Haemin crystals are seen in large numbers. The blood drop with glacial acetic acid forms acid haematin which on heating forms Haemin crystals.

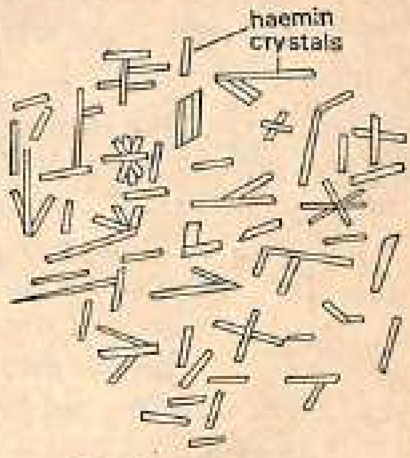


Fig. 11-6. Haemin crystals.

Chapter **12**

Chromatography

Chromatography, in modern era, forms important tool for the detection of amino acids, amines, proteins, carbohydrates, aliphatic acids, steroids, bile salts, cardiac glycosides, purines, pyrimidines, phenols, aromatic acids, indole compounds, porphyrines, pigments, antibiotics, enzymes, vitamins, pesticides, polymers, detergents and miscellaneous organic substances.

The term "chromatography" (Gk., to write in colours) was first coined by ***Michael Tswett*** (1906), a Russian botanist. He used a column of calcium carbonate to separate the components of a petroleum ether, chlorophyll extract. ***Michael*** described his results by saying that "the pigments according to the adsorption sequence are resolved into variously coloured zones—such a preparation I term a *chromatogram* and the corresponding method, the *chromatographic methods*". According to him, the method may be applicable to other coloured and colourless substances.

The great popularity of the present day chromatography is due to ***Martin***, ***Consden***, ***Gordon***, ***Synge*** (1941), ***Neubaur*** (1938), ***Weil*** and ***Williams*** (1951).

Neubaur (1938) separated neutral amino acids and observed that the partition coefficients of acetylated amino acids between water and immiscible organic solvent differed for various amino acids. ***Martin*** and ***Synge*** (1941) made a forty-plate apparatus for the continuous separation of acetylated amino acids. In order to simplify the above procedure they used inert support *silica gel* to hold one of the phases (water), and to pass immiscible solvent through a bed of water-containing silica gel. In order to eliminate the preparation of silica gel, ***Martin*** and ***Consden*** (1944) replaced silica gel by *filter paper* as the inert support. By the use of filter paper the acetylation of amino acids was not necessary and they could now be detected directly on the paper by the treatment with *ninhydrin*.

The method of **paper partition chromatography** consists in applying a small drop of solution containing substances to be separated to a strip of filter paper, a short distance from one end. The drop is allowed to dry and the end of the paper, nearest to the spot, is placed in the developing solution, usually a water-containing organic solvent, so that the solvent flows past the "spot" by capillary action and on down the length of the paper.

For chromatography, the following few rules must be observed—

(1) The composition of the flowing solvent should be kept constant througout the development. It is done by keeping the chromatogram in an enclosed chamber, the space of which is saturated with the developing solvent at constant temperature.

(2) The developing solvent should move at a relatively slow rate (2–3 cm per hour). The rate of solvent flow is dependent on the type of paper used, on the ratio of the width of the "wick" to that of paper chromatogram, on the composition of solvent and on the temperature of the chromatogram chamber.

(3) The choice of the solvent should be one in which the components to be separated have a small but definite solubility. If the substances are too soluble, they will appear at or near the solvent "front" of the chromatogram. If they are too insoluble in the

solvent, they will remain at the point of application. If the factors of adsorption and ion exchange are neglected, the movement of a substance in a paper chromatogram is a function of its solubility in the developing solvent. Thus, solvents for water soluble substances are usually water-containing organic compounds, whereas solvents for substances soluble in organic solvents but insoluble in water are often aqueous solutions of organic solvents.

In chromatography, the separation of the gradient components of a mixture is a function of their different affinities for a stationary phase such as a solid or liquid and their differential solubility in a moving phase such as liquid or gas. The main factor for the separation of compounds is the coefficient of distribution between the two phases. Separation of the compounds is governed by their tendencies to distribute themselves between solution in the liquid and absorption on the solid surface. The solid phase can be paper, starch and silica gel. The separation during chromatography is due to continually changing equilibria and the shuttling of molecules between the stationary and moving phase. The moving phase continuously carries molecules to new areas of the adsorbent where they are adsorbed. As the new solvent reaches their places, the molecules can be released into it, and travel to unoccupied areas where absorption can occur. The molecules extremely soluble in the moving phase have little affinity for the adsorbent, will move faster and a to greater distance than those having less affinity for the solvent and a greater affinity for the adsorbent.

CLASSIFICATION OF CHROMATOGRAPHIC PROCEDURE

The chromatographic procedure is classified into 3 main catagories on the basis of the nature of the solid adsorbent or support medium employed.

(A) **Column chromatography**—The bulk solids are packed into columns.
(B) **Thin-layer chromatography** (TLC)—The bulk solid is applied in a thin layer to a supporting glass or plastic plate.
(C) **Paper chromatography**—The solid is available as sheets such as paper.

R_F VALUE

In both TLC and paper chromatography the mixture to be separated is applied as a spot or a line and the chromatogram is developed. The distance travelled by a specific substance under specific set of conditions like temperature, solvent system, direction of flow and type of paper is characteristic and may be used to identify it. The relation of the distance travelled by a compound to that of the solvent front is called as R_F value. According to ***Morris*** and ***Morris*** (1964), it is defined as the "*ratio of the linear rate of movement of the solute zone to the linear rate of movement of the solvent*". R_F value may be calculated by the following formula—

$$R_F = \frac{\text{Distance from origin travelled by compound}}{\text{Distance of solvent from origin.}}$$

In some cases, where a mixture is suspected to contain compounds having similar or identical R_F values, the resolution of chromatogram can be improved by developing in two directions with two different solvent systems and it is called as *two-dimensional chromatography*. In this case, mixture is spotted at one corner of the paper or plate and is developed in one direction using a given solvent. After chromatogram is dried it is rotated 90° and developed again in a second direction in a different solvent system.

CHOICE OF FILTER PAPER

Generally Whatman No. 1 or Schleicher and Schnell filter papers are taken. A study of the suitability of various grades and types of filter paper for the separation of amino acids by different solvents resulted in the following classification of the filter papers.

(1) Degree and clarity of separations.
(2) Diffuseness of spots.
(3) Degree of formation of stains or streaks, presumably caused by the impurities in the paper.
(4) Extent of formation of tails or zones other than amino acids, giving colour reactions with ninhydrin.
(5) Deviation from vertical movement.
(6) Rate of movement of solvent front.

I. PAPER CHROMATOGRAPHY FOR AMINO ACIDS, AMINES AND PEPTIDES

(A) Solvents (For Amino Acids)

Out of several solvents employed for the separation of amino acids and peptides, the following four are the most useful :

(1) **Phenol**—100 milliliters of metal-free water is dissolved in 400 ml. of liquid phenol and 25–50 mg. of 8–hydroxyquinoline is also added. The solvent may be stored in a dark bottle in the refrigerator. Before using, shake well and gently warm. The relative distance (R_F) travelled by the more basic amino acids, arginine, lysine, ornithine, hydroxylysine in phenol is influenced by the pH of the developing medium.

(2) **Luitidine–ethanol**—This solvent is made by mixing 55 ml. of 2, 6-luitidine, 25 ml. of ethanol, 20 ml. of water and 2 ml. of diethylamine. This solvent is completely miscible.

(3) **Luitidine–collidine**—It is made by mixing 2, 6-lutidine, 2, 4, 6-collidine and water (1 part each).

(4) **Butanol-acetic acid**—This solvent is made by adding 60 ml. of glacial acetic acid to 500 ml. of a freshly shaken mixture of equal volumes of water and n-butanol. Two layers are formed. The upper layer is used as the moving phase. The following specific reagents are described for some amino acids.

(1) **Arginine**—α–naphthol-hypochlorite reaction. The chromatograms are sprayed with 0·1 per cent solution of α–naphthol in 1N NaOH. After drying, paper is sprayed with NaClO. Arginine appears as a red spot.
(2) **Cystine**—The paper is dipped into 1 per cent of Na_2SO_3 and partly dried in air. The damp chromatogram is treated with Folin's phospho-18-tungstic acid and the reagent is made alkaline with $NaHCO_3$. Cysteine and other reducing substances give a deep blue colour.
(3) **Citrulline**—This amino acid is near glutamine on two-dimensional chromatograms and is best detected by spraying with 1 per cent solution of p-dimethylaminobenzaldehyde in 1N HCl. It gives a yellow spot.
(4) **Glycine**—Glycine, histidine and tryptophan give a colour when sprayed with Zimmerman's o-ophthaldialdehyde reagent.
(5) **Ornithine**—Ornithine and glutamic acid have been reported to give three and four spots on butanol-acid chromatograms after acid hydrolysis.

(B) Separation of Free Amino Acids and Peptides in Tissues

For detecting free amino acids and peptides in plant or animal tissues, other constituents may be removed as far as possible. Dialysis or precipitation with trichloroacetic acid, tungstic acid, ferric hydroxide, zinc sulfate, barium hydroxide at pH 7·2–7·6, perchloric acid, acetone and ethanol is done. Grind the tissues with sufficient absolute ethanol in a blender, so that the final concentration of alcohol is 80 per cent by volume. The insoluble material is removed by filtration and washed with 80 per cent ethanol.

CLASS EXERCISE FOR AMINO ACIDS (Plate 1)

Object—Detection of Amino Acids by Two-dimensional Paper Chromatography

Requirements—Chromatography chamber, ethyl alcohol, phenol, water imbibed seeds or animal tissue, butanol, glacial acetic acid, water, ninhydrin, spray agent, capillary tubes, staples and stapler, spraying apparatus (atomizer), pistol mortom, conical flasks (100 ml), pencil, Whatman No. 1 paper, glass rod, spirit lamp or Bunsen's flame.

Procedure—(1) Clean the pistol-mortom. Grind 10 gm. of animal tissue or germinating seeds in 50 ml. of absolute ethyl alcohol. Grinding may be done in a blender also. Filter and evaporate the filterate to dryness. Redissolve the evaporated filtrate solid in double distilled water to make up the volume of extract to nearly 2 ml. For class students and for beginners, mixture of known amino acids may be preferred as described above. Glycine, aspartic acid, phenylalanine, tyrosine and tryptophane may be taken.

(2) Take glass-walled chromatography chamber. In one chamber fill phenol and in the other n-butanol-acetic water solvent (3 : 1 : 1) and keep the level of the solvent half an inch above the bottom of the chamber.

(3) Cut Whatman No. 1 filter paper into strips according to the size of the chromatography chamber. Mark a small circle on the cut strips by pencil about 1 inch from the bottom and 2 inches from the left hand edge. Apply a small amount of extract on the pencil-marked circle by glass rod. Hang the chromatogram with extract dot at the

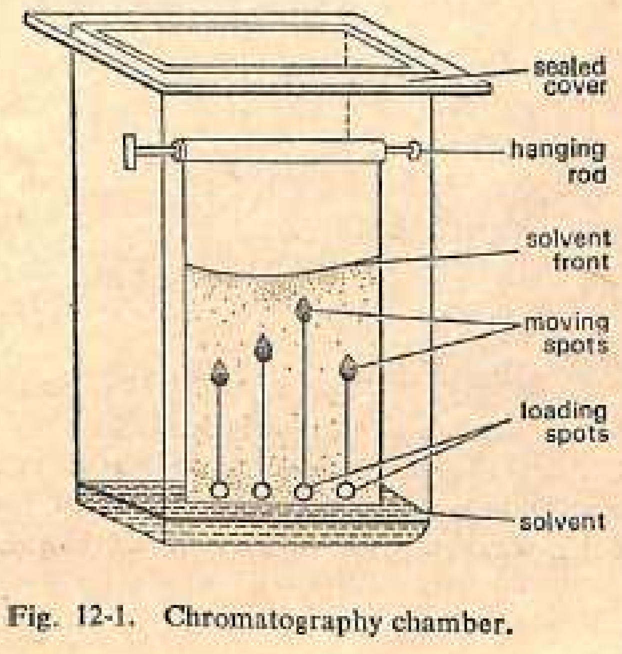


Fig. 12-1. Chromatography chamber.

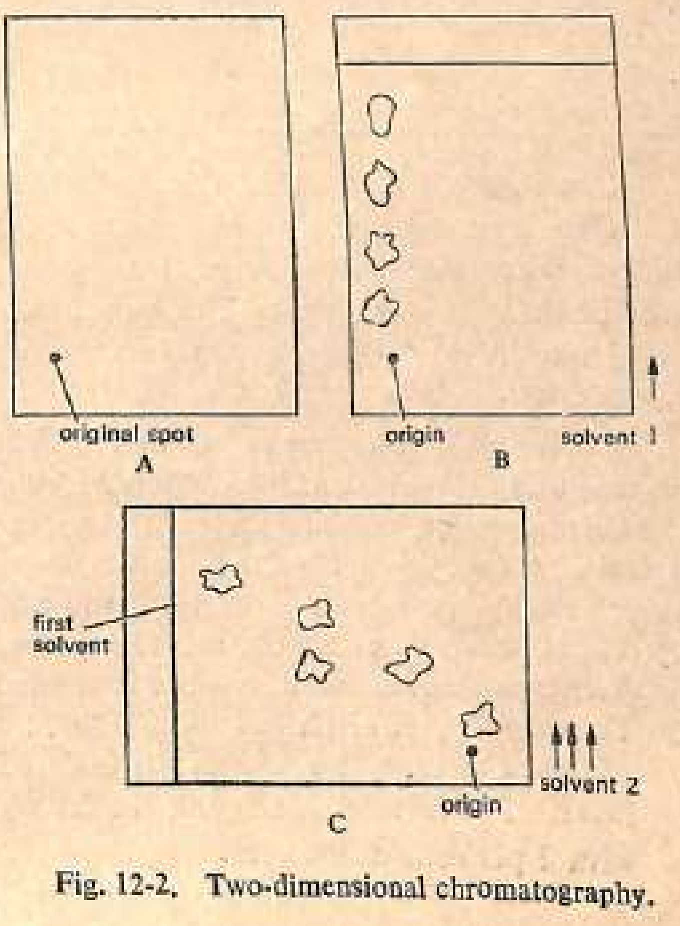


Fig. 12-2. Two-dimensional chromatography.

base and allow the extract to become dry. Dip the paper edge in the solvent, keeping the pencil mark above the solvent. Close the chamber, make it airtight and permit 16–18 hours to develop the chromatogram.

(4) Remove the chromatogram and let it become dry marking the position of the solvent. Turn the paper 90°, place the paper in this direction in another chamber containing solvent or n-butanol-acetic acid water. Let the chromatogram develop for 10–12 hours in chromatography chamber. Remove the paper and spray uniformly with 0.1 per cent ninhydrin (0.1 gm of ninhydrin mixed in 100 ml saturated n-butanol water). Heat the paper at 90°C for 2–5 minutes. Circle the spots with pencil.

(5) Calculate the R_F value and compare it with standardised values. Different colours are given by different amino acids,

R_F Values for Certain Amino Acids in Different Solvents

(After ***Block***, ***Durrum*** and ***Zweig***—*Paper Chromatography*).

Amino acids	Solvents				
	Acetone-urea water	1, Butanol-acetic acid water	2,6 Lutidine-collidin water	Phenol water	Pyridine-ethanol water
1. α-Alanine	0.34	—	0.28	0.60	0.54
2. ω-Alanine	—	0.37	0.22	0.66	—
3. Arginine	0.34	—	0.17	0.89	0.31
4. Aspartic acid	0.18	—	0.21	0.19	0.43
5. Cystine	0.16	—	—	—	—
6. Glutamic acid	0.18	—	0.20	0.31	0.48
7. Glycine	0.21	—	0.12	0.12	—
8. Histidine	0.25	—	0.27	0.69	0.43
9. Isoleucine	0.59	—	0.54	0.84	0.66
10. Lysine	0.25	—	0.11	0.81	—
11. Methionine	0.55	—	0.42	0.81	0.66
12. Proline	0.56	—	0.28	0.88	0.56
13. Ornithine	0.65	—	0.11	0.79	—
14. Serine	0.20	—	0.28	0.36	0.51
15. Phenylalanine	0.63	—	0.48	0.85	0.66

II. PAPER CHROMATOGRAPHY FOR CARBOHYDRATES

One- and two-dimensional paper chromatography makes it possible to separate various sugars. Polysaccharides may be hydrolyzed and hydrolyzates may be treated like other simple sugar mixtures. The quantitative evaluation of the sugar chromatographs can be achieved by a visual or photoelectric comparison of the optical density of the coloured spots.

Choice of the filter paper—Generally Whatman No. 1 filter paper is preferred but Schleicher and Schnell No. 589 and white ribbon may also be used.

Solvents—For chromatographic development of sugars, ascorbic acid and related substances, the following solvents must be specially treated to retard the decomposition of ascorbic acid by heavy metal ions present in the paper or solvents :

(1) 60 milliliters of n-butanol is shaken with 40 ml. of water and an excess of oxalic acid. The mixture is allowed to settle in a separatory funnel. Use upper layer.

(2) Dissolve 50 gm. of phenol crystals in 10 ml. of charcoal-filtered water and add excess of oxalic acid. The mixture is allowed to settle in a separatory funnel and use lower layer. For further refinement, the filter paper is washed prior to solvent development with 2 per cent oxalic acid.

(3) The presence of inorganic salts Na_2SO_4, Na_3PO_4 often produces artifacts and retardation of spots with basic solvents. However, the solvents n-propanol : ethyl acetate : water (7 : 1 : 2) gives excellent result for sugar chromatography.

(4) For two-dimensional separation of many simple sugars, phosphorylated sugars, organic acids, the following solvent pair is recommended :

(a) ***First direction***—Liquid phenol water (100 : 20). The mixture is neutralized to pH 5-6.

(b) ***Second direction***—(A) Butanol water, (B) Propionic acid water. Just before use mix equal volumes of A and B and warm slightly to form a single phase solvent.

(5) The following pair may be used for two-dimensional ascending chromatography :

(a) ***First direction***—n-Butanol : pyridine : water (3 : 2 : 1·5).

(b) ***Second direction***—Phenol saturated with ammonical water and small amount of 8-quinolinol.

(6) For the separation of sucrose, glucose, fructose and sorbitol the following solvents are recommended :

(a) ***First direction***—Benzene : n-butanol : pyridine : water (1 : 5 : 3 : 3).

(b) ***Second direction***—Amyl alcohol : pyridine : water (1 : 1 : 2).

R_F Values of Some Sugars (After *Block*)

Sugars	Solvent Systems			
	Water-saturated phenol + 1 per cent NH_3	Water-saturated collidine	n-Butanol : acetic acid : water (Descending)	n-Butanol : acetic acid : water (Horizontal)
D-Glucose	0.39	0.39	0.18	0.43
D-Galaclose	0.44	0.34	0.16	0.41
D-Mannose	0.45	0.46	0.20	0.46
D-Fructose	0.51	0.42	0.23	0.48
D-Xylose	0.44	0.50	0.28	0.53
Lactose	0.38	0.24	0.09	0.33
Sucrose	0.39	0.40	0.14	0.39
Maltose	0.36	0.32	0.11	—
D-Deoxyribose	0.73	0.60	—	—

CLASS EXERCISE OF SUGAR CHROMATOGRAPHY

Object—Separation of Sugars by Paper Chromatography

Requirements—Some unknown 1 per cent sugar solutions (preferably from some plant extract), 1 per cent solutions of glucose, fructose, rhamnose, sucrose, arabinose, ribose and galactose, solvent I (t-butanol : glacial acetic acid : water, 3 : 1 : 1—300 ml.), solvent II (phenol : water, 4 : 1—30 ml.), spray agent p-anisidine, 2 chromatography jars (10 by 18 inches) with ground glass lids, grease, oven maintained at 80°C, chromatography paper Whatman No. 1, pencil, ruler, scissors, micropipette and atomizer or other spray device.

Procedure—(1) The chromatography jars should be made airtight. Apply a little grease over the mouth rim of the jar. Mark the jars A and B. Keep solvent I in jar A and solvent II in jar B. Each jar should contain one half inch of the solvents. Cover the jars and allow the internal atmosphere to equilibrate for several hours before the use.

(2) Cut 2 strips of Whatman No. 1 chromatography paper, according to the size of the chromatography jar. The papers should be cut carefully, avoiding any contact with fingers or other substances which might contribute interfering chemicals.

(3) Lay two cut strips of paper on a clean surface with long axis parallel to the table edge. Draw a pencil line two inches above the edge of one of the long sides. Make a series of pencil dots at one inch intervals along the line and label these dots as fructose, glucose, sucrose, arabinose, ribose and rhamnose. The two papers or strips should be duplicate which will be kept into separate solvents.

(4) Arrange the sheets to overlap a support such as a glass tube or meter stick in such a way that the pencil spots are raised above the surface of the table.

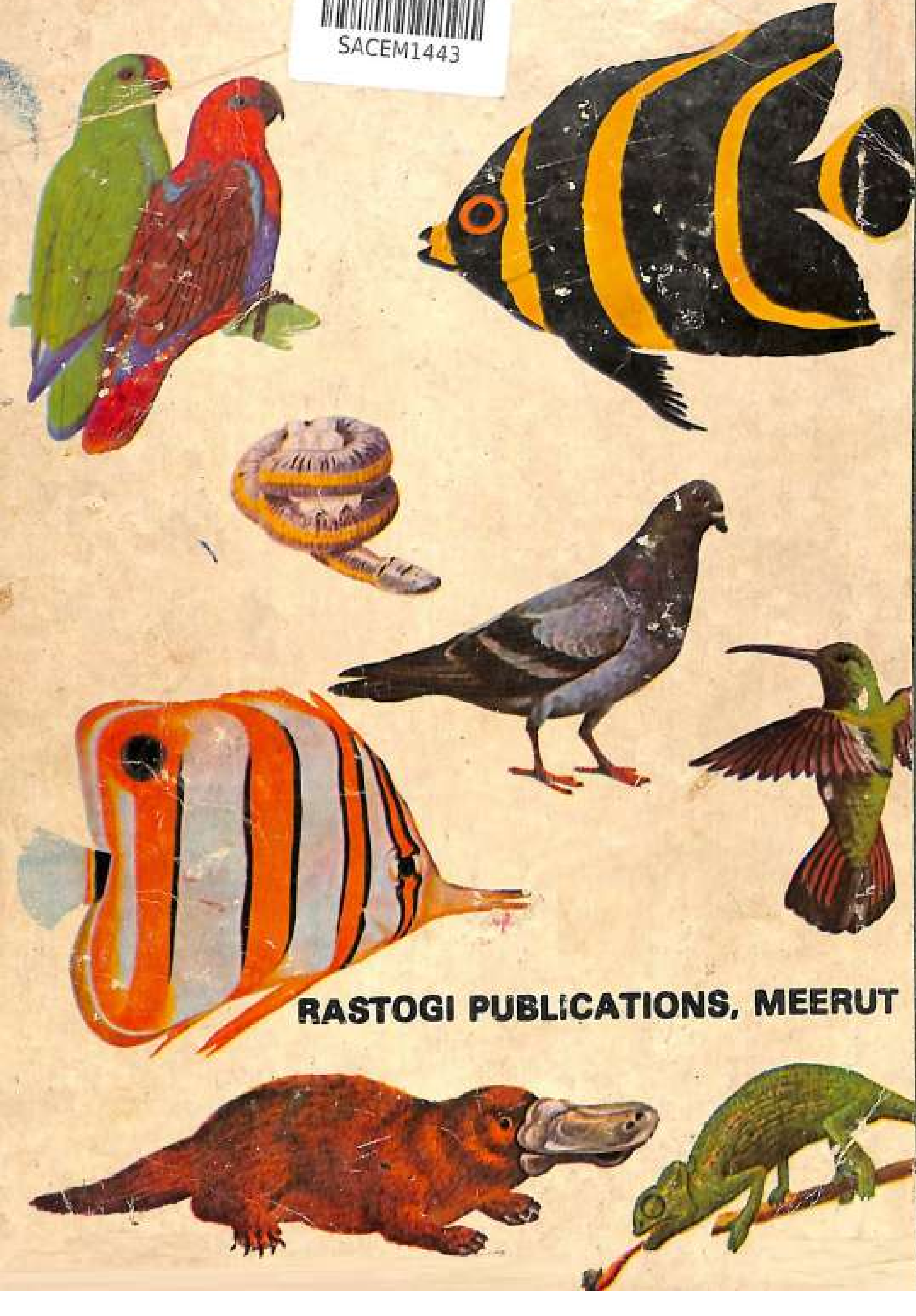
(5) Apply intermittently 3 micromilliliter of sugar solutions on the appropriate spot and allow them to become dry.

(6) Now staple the dry sheets separately in such a way as to form a cylinder and this chromatogram may be allowed to develop in solvent I and II separately for 10–12 hours. Cover the jars and leave the chromatogram until the solvent front approaches the upper edge of the paper.

(7) After development, mark the solvent front and hang the papers to dry. When dry, spray the papers with p-anisidine reagent with atomizer and keep the chromatograms in 80°C maintained oven for 3 minutes. Circle the resulting spots with pencil and note the colour. Calculate the R_F values of each sugar and compare with standard values. Make a table showing results.

Table Showing Result of Ascending Paper Chromatography of Known Sugars/(Unknown Sugars)

Compound	R_F value in solvent I—colour	R_F value in solvent II—colour
1. Glucose		
2. Fructose		
3. Rhamnose		
4. Arabinose		
5. Sucrose		
6. —		



RASTOGI PUBLICATIONS, MEERUT